ACETYLENE

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A HANDBOOK FOR THE STUDENT AND MANUFACTURER

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PREFACE

DURING the past six years the manufacture of calcium carbide and the installation of apparatus for lighting by Acetylene has become so important an industry, that the time seems to have arrived when a book on the subject, which should gather together not only the information gleaned in recent years, but also the immense mass of facts discovered with regard to Acetylene in the sixty-four years which have elapsed since its discovery by Edmund Davy, in 1836, would not be unacceptable to those interested in this beautiful illuminant.

France possesses no less than three handbooks dealing with the subject, whilst Germany has Herr Liebetanz' excellent work, *Calciumcarbid und Acetylen*, and also the translation of M. Pellissier's French work from the facile pen of Dr. Anton Ludwig; but so far no textbook worthy of the name has been published in the English language, although an excellent translation of Perrodil's *Le Carbure de Calcium et l'Acetylene* appeared in serial form in the pages of the *Progressive Age*, which, as far as the

author knows, has not been republished in book form.

In writing this book the difficulty soon arose that in attempting to make it a complete record of the work that has been done, risk was run of overloading the technical side of the question with scientific researches which, although invaluable to a student working on the subject of Acetylene, would not be welcomed by a generator maker desirous of finding the reasons for the overheating of a special form of apparatus; and in order to as far as possible avoid this difficulty the book has been written in two divisions, the first part devoted to the scientific side of the preparation and properties of Acetylene, whilst the second part deals with the technical developments of the last few years considered from a scientific standpoint.

The foreign textbooks on the subject have all been written by engineers who have presented the subject from the point of view most familiar to them, and although the present work may be found not so full of mechanical detail, it is hoped that the subject may not have suffered thereby. In order to make the book as useful as possible to those engaged in practical work on Acetylene, a third part has been added containing the legal enactments of various countries, a list of the patents

taken out in this country with a *précis* of their contents, and an Appendix of useful data.

The author desires to express his grateful thanks to Dr. Polis, late Professor of Chemistry at the Technical School of Aix-la-Chapelle, for the aid he has given in the first part of the book, and also to his assistants and all those who have so kindly helped with data and drawings of special apparatus; whilst especially does he desire to acknowledge the aid given by Mr. F. G. Worth, the Managing Director of the Acetylene Illuminating Company, who from the first introduction of calcium carbide has done all in his power to encourage scientific research into the manufacture of carbide, and the questions arising therefrom.

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LIST OF ABBREVIATIONS OF REFERENCES IN TEXT

Amer. Chem. Jour.—American Chemical Journal.
Ann. Chim. Pharm.—Annales de Chimie et de Pharmacie.
Ann. Chim. Phys.—Annales de Chimie et de Physique.
Berl. Ber.—Berliner Akademie-Berichte.
Brit. Assoc. Rep.—British Association Reports.
Bull. Soc. Chim.—Bulletin de la Société Chimique de Paris.
Chem. News—Chemical News.
Chem. Soc. Jour.—Journal of the Chemical Society of London.
Compt. Rendu.—Comptes Rendus de l'Académie des Sciences.
Dingl. Pol. Jour.—Dingler's Polytechnisches Journal.
Chem. Zeit.—Zeitschrift für Chemie.
Jour. Franklin Instit.—Journal of the Franklin Institute.
Jour. f. Gasbeleuchtung—Journal für Gasbeleuchtung.
Jour. Chem. Soc. Ind.—Journal of the Society of Chemical Industry.
Jour. Prakt. Chem.—Journal für Pracktische Chemie.
Jour. Soc. Arts—Journal of the Society of Arts.
Lieb. Ann.—Liebig's Annalen der Chemie.
Pogg. Ann.—Poggendorf's Annalen der Physique und Chemie.
Proc. Roy. Soc.—Proceedings of the Royal Society.
Thermoch. Unters.—Thermochemische Untersuchungen.
Trans. Amer. Instit. Min. Eng.—Transactions of the American Institute of Mining Engineers.
W. & I.—Acetylene in Wissenschaft und Industrie.
Wagner Jahresb.—Wagner Jahresbericht.
Zeit. Electrochem.—Zeitschrift für Electrochemie.
Zeit. f. Chem.—Zeitschrift für Chemie.
Zeit. f. Calc. Acet.—Zeitschrift für Calciumcarbid Fabrikation und Acetylen Beleuchtung.
Zeit. f. Anorg. Chem.—Zeitschrift für Anorgischen Chemie.

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Part I

SCIENTIFIC

CHAPTER I

THE HISTORY OF ACETYLENE

From its Discovery by Edmund Davy in 1836 to the Introduction of Commercial Acetylene in 1895

ACETYLENE occupies a position almost unique in the history of useful discoveries, as, long before we had the power of producing it commercially, its properties had attracted much scientific interest.

Many people at the present time seem to consider that our knowledge of this beautiful illuminant is of modern date, whilst all that the last decade has brought forth has been little more than the discovery of how to produce the gas on a commercial scale, and details as to its properties and behaviour in every-day use.

Discovery of Acetylene, 1836

The original discovery of the gas is due to Edmund Davy, Professor of Chemistry to the Royal Dublin Society, and it was at a meeting of this body in March, 1836, that he first described some of its more important properties, whilst in the autumn of that year he introduced his discovery to the British Association at their Bristol meeting.

Edmund Davy's communication to the British Association

Edmund Davy's communication[1] to the British Association is so clear and concise that it is well to reproduce it here *in extenso*.

"Early in the present year the author, in attempting to procure potassium by strongly heating a

[1] British Association Reports, 1836, 62.

mixture of calcined tartar and charcoal in a large iron bottle, obtained a black substance which readily decomposed water and yielded a gas which, on examination, proved to be a new compound of carbon and hydrogen. This gas is highly inflammable, and when kindled in contact with air burns with a bright flame, apparently denser and of greater splendour than even olefiant gas. If the supply of air is limited the combustion of the gas is accompanied with a copious deposition of carbon. When the new gas is brought in contact with chlorine gas instant explosion takes place, accompanied by a large red flame and the deposition of much carbon; and these effects readily take place in the dark, and are, of course, quite independent of the action of the sun's rays or of light.

Properties of Acetylene first discovered

"The new gas may be kept over mercury for an indefinite time without undergoing any apparent change, but it is slowly absorbed by water. Distilled water recently boiled, when agitated in contact with the new gas, absorbs about its own volume of it; but on heating the aqueous solution the gas is evolved apparently unaltered. The new gas is absorbed to a certain extent by, and blackens, sulphuric acid. It detonates powerfully when mixed with oxygen gas, especially if the latter forms three-fourths or more of the mixture; and the only products of its combustion with oxygen are carbonic acid gas and water.

"The new gas requires for its complete combustion two and a half volumes of oxygen gas, which are converted into two volumes of carbonic acid gas and water.

Composition as given by Davy

"From the author's analysis of the new gas by different methods it appears to be composed of one volume of hydrogen and two volumes of the vapour of carbon condensed into one volume. Hence the

new gas contains as much carbon, but only half the quantity of hydrogen, that is in olefiant gas. The density of the former is therefore less than that of the latter by the weight of a volume of hydrogen equal to its own bulk. The new gas is, in fact, a *bicarburet of hydrogen*, composed of two proportions of carbon and one of hydrogen, and may be represented by the formula $C^2 + H^1$ or $2C + H$, and differs in constitution, the author presumes, from that of any other known compound of carbon and hydrogen.

Possibility of using Acetylene as an illuminant

"From the brilliancy with which the new gas burns in contact with the atmosphere, it is, in the opinion of the author, admirably adapted for the purposes of artificial light if it can be procured at a cheap rate."

In reading this intensely interesting communication it must be borne in mind that Davy was using the system of symbolical representation then in vogue, and under which ethylene or olefiant gas was represented as C_2H_2, instead of, as at present, C_2H_4, so that in stating that "the new gas contained as much carbon, but only half the quantity of hydrogen that is in olefiant gas" he was absolutely correct.

The concluding sentence of Davy's paper also shows that he grasped the commercial possibilities of acetylene as an illuminant, whilst his method of preparing the gas by acting upon potassium carbide with water is only a step removed from the reaction which has to-day rendered acetylene available for the purpose foreshadowed by its discoverer.

Torrey, 1839

In 1839 Torrey[1] noticed in the gas mains of New York, which at that time were made of copper, the formation of a brown deposit which could be exploded by a blow or by heat, and which was probably the acetylene-copper compound.

Another remarkable observation was made four

[1] *Americ. Gas Light Jour.*, Oct., 1859.

years later, when in 1840 Hare[1] noticed that on heating mercuric cyanide with lime a black residue containing carbon was produced, and on heating this *in the electric arc* a black mass formed, which developed a gas possessing an unpleasant odour when water was poured on it.

Hare makes Calcic Carbide in Electric Arc 1840

It is evident that Hare not only made calcic carbide by electric fusion, but decomposed it with evolution of acetylene by the action on it of water, although he had no idea of the compound with which he was dealing, nor of the reactions taking place.

Quet, 1858, makes Acetylene by action of the spark on Alcoholic Potash

From this date until 1858 nothing appears to have been done bearing upon the subject of acetylene, but in that year Quet[2] obtained in one hour, by the action of an induction spark upon alcoholic potash, nearly a litre of a gas which gave a red precipitate with ammoniacal cuprous chloride. This substance, after drying in a vacuum over sulphuric acid, or by heating on the water bath, became brown, and detonated with development of light when heated to a temperature a little over 120° C., or when struck with a hammer. He also found that this compound, when gently heated with hydrochloric acid, liberated a gas which had the property of burning with a bright flame and of forming carbon dioxide.

First use of Ammoniacal Cuprous and Silver Solutions to detect Acetylene

The gas thus formed by the action of electric sparks on alcoholic potash yielded a white precipitate when passed through ammoniacal silver solution, which turned yellow in air and became grey when dried. And this compound, like the precipitate formed by the action of the gas on ammoniacal cuprous chloride, detonated by a blow, or when heated to 100° C.

Acetylene produced by passing Alcohol Vapour through red-hot tube

The same gas was also produced by passing the vapour of alcohol through a red-hot porcelain tube,

[1] *L'Institut*, 1840, 312. Berzelius, *Lehrbuch*, fünfte Aufl., vol. 2, 152.

[2] *Compt. Rend.*, 46, 903; *Ann. Chem. Pharm.*, 108, 116.

and when bubbled through ammoniacal cuprous chloride or silver solutions, the same detonating compounds were formed.

Vogel and Reischauer, 1858

In the same year also Vogel and Reischauer[1] noticed that a precipitate was formed on bubbling coal gas through a neutral silver nitrate solution, and that this precipitate would explode on heating or on a blow with a hammer. By acting on the compound with hydrochloric acid a gas was set free which had the odour of coal gas and burnt with a bright flame. This gas, passed again through the silver solution, yielded once more the explosive silver precipitate. They found that the quantity of silver present in the precipitate was from 78·3 to 84 per cent., and also that the quantity of this gas in coal gas seemed to vary.

The presence of Acetylene in coal gas proved

Boettger, 1859, Acetylene in the products of destructive distillation

During 1859 Boettger[2] made some researches on the action of common coal gas and of the gas made by the destructive distillation of resin, or of a mixture of Boghead coal and resinous wood, on different solutions, and found that, when passing these gases through ammoniacal cuprous chloride, cinnabar red flakes were formed in a short time; and that after several hours they increased to such an extent that the whole of the lower part of the bottle was filled with them. Boettger was of opinion that the body in question was a compound of copper with a hydrocarbon, and he also succeeded in making the analogous gold and silver compounds, and confirmed their explosive properties as noticed by Vogel and Reischauer.

The period 1858–1859 may be taken as marking the discovery of the formation of metallic acetylides, and also of the fact that acetylene is formed by the action of heat on hydrocarbons and on such com-

[1] *Jahresber.*, 11, 208.
[2] *Ann. Chem. Pharm.*, 109, 351.

pounds as alcohol, and is produced during destructive distillation, being consequently found in the gaseous products of all such processes.

Berthelot's first research on Acetylene, 1860

The recognition of these facts was the forerunner of the great discoveries which commenced with the publication by Berthelot[1] in 1860 of the first of his classical researches upon acetylene. In this paper Berthelot made no mention of the work of previous observers, and it is not clear whether he knew how much had already been done. It was in this paper that the name "acetylene" was first bestowed upon the compound, and Berthelot, having determined the composition by careful eudiometric analysis and having ascertained that its specific gravity was 0·92, adopted for it the formula C_2H_2, and pointed out that it was the simplest member of the C_nH_{2n-2} series.

Specific gravity and composition

Acetylene formed by passing Organic Vapours through red-hot tubes

He prepared the gas by allowing the vapours of alcohol, ether, aldehyde, methylic alcohol, methane and styrolene, to pass through red-hot tubes, and found that he obtained the best yield with ether. The vapour of chloroform when passed over red-hot copper also gave some acetylene, and finally he stated that it occurred in coal gas. In order to isolate the acetylene from other gaseous products always formed at the same time, he passed it through ammoniacal cuprous chloride and decomposed the well-washed copper compound by hydrochloric acid.

He described the acetylene as a colourless gas, fairly soluble in water, and of a specific and somewhat disagreeable odour, burning with a bright, smoky flame, and exploding when mixed with chlorine.

Action of Sulphuric Acid on the gas

He further stated that sulphuric acid would absorb the gas, and he prepared the acetyl-sulphuric acid, and from this the acetyl-alcohol was made. Finally, he succeeded in making ethylene from acetylene by

[1] *Compt. Rendus*, 50, 805; *Ann. Chem. Pharm.*, 116, 116.

the action of nascent hydrogen prepared from zinc and ammonia on copper acetylide.

$$C_2H_2 + H_2 = C_2H_4.$$

In 1861 Miasnikoff[1] prepared acetylene from vinyl chloride C_2H_3Cl and vinyl bromide C_2H_3Br by the decomposition of their vapours by hot alcoholic potash, **Preparation from Vinyl Chloride or Bromide**

$$C_2H_3Cl + KHO = KCl + H_2O + C_2H_2$$
$$C_2H_3Br + KHO = KBr + H_2O + C_2H_2.$$

The gas so liberated was led into ammoniacal silver solution and silver acetylene formed, whilst he also made very accurate eudiometric analyses of the gas.

In the same year Sawitsch[2] obtained acetylene by the action of alcoholic potash on ethylene bromide **Preparation from Ethylene Bromide**

$$C_2H_4Br_2 + 2KHO = 2KBr + 2H_2O + C_2H_2,$$

and also by heating vinyl chloride with sodium ethylate or amylate.

$$C_2H_3Br + C_5H_{11}ONa = C_5H_{11}OH + NaBr + C_2H_2.$$

1862 saw the publication of the second instalment of Berthelot's great work,[3] in which he showed that the action of heat, or better, an intense induction spark, split up methane, with formation of acetylene and hydrogen— **Berthelot's second research, 1862**

$$2CH_4 = C_2H_2 + 3H_2;$$

and in the same year he discovered[4] the direct synthesis of acetylene from its elements. First, retort carbon, purified by heating in air and chlorine, was raised to an intense temperature in a current of hydrogen, but no acetylene was formed. He then tried allowing induction sparks to pass between carbon **Action of the induction spark on Methane** **Synthesis of Acetylene, 1862**

[1] *Ann. Chem. Pharm.*, 118, 330.

[2] *Rep. de Chimie pure*, 1861, 98; *Ann. Chem. Pharm.*, 119, 182.

[3] *Compt. Rend.*, 54, 515; *Ann. Chem. Pharm.*, 123, 207.

[4] *Compt. Rend.*, 54, 640; *Ann. Chem. Pharm.*, 123, 212.

pencils purified in the same way, and still no acetylene was produced. At length, trying the influence of the electric arc when formed between poles of purified carbon in an atmosphere of hydrogen, he found that, under these conditions, combination of the two elements took place, acetylene being thus synthesised.

The best carbons for synthesis of Acetylene

In another communication[1] he repeated his experiments on the synthesis of acetylene, using different kinds of carbon to form the poles, and found that retort carbon and graphite gave the best results, whilst charcoal produced the worst; and finally he again stated that the induction spark, even when tried under different conditions, yielded no acetylene.

Acetylene and Chlorine

Later on[2] he showed that acetylene would explode when mixed with chlorine, and that carbon was at the same time liberated, and also stated the possibility of forming acetylene dichloride. He found that acetylene might be formed by decomposing chloroform in a red-hot tube, and also by allowing a mixture of hydrochloric acid gas and carbon monoxide to pass through a red-hot tube, and he came to the conclusion that, in most cases, the decomposition of organic substances under the influence of a red heat would yield this gas.

Copper Acetylene

In this paper he also examined the copper compound formed by acetylene, and wrote of it: "Besides its production from ammoniacal cuprous chloride it can also be made by means of a solution of cuprous chloride in potassic chloride when acetylene is bubbled through it. Under these conditions the copper compound is produced immediately, but its formation stops very soon; on adding, however, a little potassic hydrate to the solution, its formation recommences. The compound so formed has the same explosive properties as

[1] *Compt. Rend.*, 54, 1042; *Ann. Chem. Pharm.*, 123, 214.
[2] *Compt. Rend.*, 54, 1044; *Ann. Chem. Pharm.*, 123, 215.

when it is prepared from the ammoniacal cuprous chloride.

The compound cannot be freed from oxygen, and the formula representing it seems to be

$$Cu\,HC_2 + nCu_2\,O.$$

The body explodes when heated to nearly 120° C., and water, copper, carbon dioxide, together with a trace of carbon monoxide are produced.

Action of Acetylene in coal gas

In another communication[1] he noted the presence of acetylene in coal gas, the amount of which does not exceed 1 in 10,000, but it has a slight influence on the lighting power and helps to give the characteristic smell to the gas.

Reboul makes Acetylene from Ethylene Chloride

During 1862, Reboul[2] reviewed the results obtained by Miasnikoff and Sawitsch, and made acetylene by allowing ethylene chloride to drip into boiling alcoholic potash, condensing the alcohol which distils over in wash bottles, and succeeded in getting $1\frac{1}{2}$ litres of impure acetylene per 20 cc. of ethylene chloride.

Woehler discovers Calcic Carbide, 1862

The most important scientific achievement, however, that marks the history of our subject in the year 1862 was the discovery by the great German chemist, Woehler,[3] of the formation of calcic carbide and its decomposition by water with evolution of acetylene. He found that at very high temperatures carbon acted upon an alloy of zinc and calcium,—obtained a short time before by Caron,—and that a carbide of calcium was produced, the zinc at the same time distilling off, and it was in this paper that for the first time the name "carbide of calcium" was mentioned. He also found that this compound had the property of being decomposed by water with the formation of calcium hydrate and acetylene. He did not analyse the gas,

Action of water on Calcium Carbide

[1] *Compt. Rend.*, 54, 1070.
[2] *Compt. Rend.*, 54, 1229; *Ann. Chem. Pharm.*, 124, 267.
[3] *Ann. Chem. Pharm.*, 124, 220.

but identified it by the brilliancy of its flame, by its exploding when mixed with chlorine, and by the formation from it of silver acetylene.

Kekulé forms Acetylene by Electrolysis

Two years later, in 1864, Kekulé[1] formed acetylene by the electrolysis of the sodium salts of fumaric and malleinic acids, and in 1865 Vohl[2] obtained acetylene by the decomposition of oils in red-hot tubes. From amylhydride and from American petroleum he obtained a gas which contained 20 per cent. of acetylene.

Berthelot discovers Acetylene in the products of incomplete combustion

During 1866, Berthelot[3] discovered acetylene in the products of incomplete combustion of many organic substances, and showed that on burning coal gas, ethylene, etc., acetylene is formed, and its presence can be demonstrated by its forming a precipitate when the products are led through a solution of ammoniacal cuprous chloride. He obtained the best results when burning ether, amylene, and benzol.

McLeod makes Acetylene by burning Oxygen in Methane

In the same year also, McLeod[4] constructed an apparatus for showing the preparation of acetylene for lecture purposes, and burnt oxygen in methane and coal gas, the products being aspirated through an ammoniacal cuprous chloride solution, the red precipitate demonstrating the formation of acetylene.

Action of Potassium Amalgam on Chloroform

It was in 1866 also that Kletzinsky[5] made an amalgam of mercury and potassium by melting them together under naphtha, and this amalgam, when heated with chloroform, yielded acetylene. In the same year also Fittig[6] found that traces of acetylene were produced when a mixture of chloroform, ether, and other hydrocarbons was acted upon by sodium; this decomposition, however, takes place very slowly and is very incomplete.

[1] *Ann. Chem. Pharm.*, 131, 85.

[2] *Dingl. Pol. Jour.*, 177, 58.

[3] *Compt. Rend.*, 62, 44; *Ann. Chem. Pharm.*, 138, 241.

[4] *Jour. Chem. Soc.* (2) 4, 151.

[5] *Zeitsch. f. Chem.*, 2, 127. [6] *Zeitsch. f. Chem.*, 2, 127.

Sabanejeff makes Acetylene by the action of hot Alcoholic Potash on Ethylene Dibromide

In 1867, Sabanejeff[1] published an improved method for making acetylene, based on the researches of Miasnikoff, Sawitsch, and Reboul. Concentrated alcoholic potash was heated over a water bath in a flask to which was fitted a reflux condenser, and ethylene dibromide allowed to drip into the alcoholic potash; the gas so generated was then led through more boiling alcoholic potash, which decomposed any traces of ethylene dibromide or monobromide which might have been brought over as vapour, whilst a second condenser and wash bottles removed any other impurities from it. In order to purify it thoroughly he absorbed the gas with ammoniacal cuprous chloride, the acetylide so formed being afterwards decomposed by hydrochloric acid, the quantity of acetylene obtained being from 60 to 75 per cent. of the theoretical yield.

Rieth notices Acetylene in products from Bunsen burner when alight at bottom

In the same year Rieth[2] prepared acetylene from a Bunsen burner the flame of which had struck back to the bottom, by aspirating the products of incomplete combustion through copper solution and decomposing the acetylide formed with hydrochloric acid. Working in this way he obtained in twelve hours nearly 100 grams of the copper precipitate.

Acetylene from Silver Acetate and Iodine

During 1869, Birnbaum[3] made acetylene by heating silver acetate with iodine, the gas evolved consisting of nearly equal volumes of acetylene and hydrogen; and in this year also Berthelot[4] prepared it by melting ethylene disulphonate of potassium with potassic hydrate—

$$C_2H_4(SO_3K)_2 + 2KHO = 2K_2SO_3 + 2H_2O + C_2H_2;$$

but the acetylene so obtained contained a large proportion of hydrogen.

[1] *Ann. Chem. Pharm.*, 178, 111.
[2] *Zeitsch. f. Chem.*, 2, 598.
[3] *Ann. Chem. Pharm.*, 152, 111.
[4] *Compt. Rend.*, 69, 563; *Ann. Chem. Pharm.*, sup., 7, 373.

Berthelot makes Acetylene by action of silent discharge on Hydrocarbon Vapours

In 1872, Berthelot[1] prepared the gas by leading hydrocarbon vapours, suspended in a current of hydrogen, through an ozone tube and exposing the mixture to the action of the silent discharge; and in the same year Odling[2] showed that acetylene was formed in small quantities when methane and carbon monoxide were passed through a red-hot tube—

$$CH_4 + CO = C_2H_2 + H_2O.$$

De Wilde

During 1874, De Wilde[3] observed that ethylene chloride was decomposed in a red-hot tube filled with lime or soda-lime, and a good yield of acetylene obtained—

$$C_2H_4Cl_2 + CaO = CaCl_2 + H_2O + C_2H_2$$
$$C_2H_4Cl_2 + 2NaHO = 2NaCl + 2H_2O + C_2H_2.$$

He absorbed the gas so produced in ammoniacal cuprous chloride solution, from which he afterwards prepared acetylene by acting upon it with hydrochloric acid.

Action of Platinum Black on Acetylene mixed with Hydrogen

He further states that platinum black has the power of causing the combination of hydrogen with acetylene to form ethane.

$$C_2H_2 + 2H_2 = C_2H_6.$$

In an earlier paper, Berthelot had shown that the action of heat upon acetylene gas polymerised it into benzene C_6H_6, and styrolene C_8H_8; but the action of the induction spark seems to produce other changes, a brown oily substance being formed, which solidifies after a few hours.

Pizarello forms Acetylene by sparking Ether Vapour

In 1877 Truchot[4] obtained acetylene by passing induction sparks through different hydrocarbon gases and vapours, whilst Pizarello[5] in 1878 found that ether vapour is decomposed by sparks from an induction coil with formation of carbon monoxide, acetylene and hydrogen; and in 1879 Haller[6] made acetylene by

[1] *Compt. Rend.*, 74, 1462. [2] Watt's *Dictionary*, 1, 1111.
[3] *Bul. Acad. Belge*, (2) 19, No. 1; *Berl. Ber.*, 7, 352.
[4] *Compt. Rend.*, 84, 717. [5] *Gazz. Chim.*, 15, 233.
[6] *Dissert. Nancy*, 1879.

the action of sodium on camphor dissolved in chloroform and toluene, and found that the sodium salt of camphor gave with chloroform a good yield of the gas.

Jungfleisch's Apparatus

In 1880 Jungfleisch[1] constructed a special apparatus in which he burnt air and coal gas, and, after cooling the escaping mixture of gases, allowed them to bubble through ammoniacal cuprous chloride, which absorbed the acetylene evolved as a product of incomplete combustion. In the same year, also, Jahn[2] stated that when alcohol was decomposed in the presence of zinc dust by heating to a dull red heat, small traces of acetylene were produced, and also traces of methane and carbon monoxide.

Dewar synthesises Acetylene in a heated tube

During 1880, also, Dewar[3] synthetically prepared acetylene by leading hydrogen through a tube made of retort carbon heated to a white heat by means of the electric current.

In 1881 Kutscheroff[4] found that acetylene was produced by the action of lead oxide on vinyl bromide in a closed tube, and in the next year (1882) Tommasi[5] recognised acetylene in the products obtained by heating copper acetate in a closed tube; whilst in 1883 Cazeneuve[6] made the gas by acting on iodoform with metallic silver—

Action of metals on Iodoform

$$2CHI_3 + 6Ag = 6AgI + C_2H_2,$$

a reaction which also takes place when zinc, iron, or mercury is employed in place of the silver.

Destrem,[7] in 1884, allowed the discharge of an induction coil to take place in benzol. A gas was set free, consisting of 42 to 43 per cent. of acetylene and 57 to 58 per cent. of hydrogen, whilst in the same year Johnson[8] described an apparatus for the production of acetylene by incomplete combustion.

[1] *Compt. Rend.*, 90, 365.
[2] *Berl. Ber.*, 13, 983, 2107.
[3] *Proc. Roy. Soc.*, 30, 88.
[4] *Berl. Ber.*, 14, 1532.
[5] *Bull. Soc. Chim.*, (2) 38, 156.
[6] *Comp. Rend.*, 97, 1371.
[7] *Comp. Rend.*, 99, 138.
[8] *Chem. News*, 49, 127.

Acetylene from Bromoform and Silver Powder

In 1891 Cazeneuve[1] prepared the gas from bromoform and powdered silver. The reaction was sometimes so intense that the silver became red hot. This method gave a nearly theoretical yield. Another mode of preparation consisted in acting upon 50 gr. of zinc dust and 20 gr. of bromoform with a 2 per cent. solution of cupric chloride. The mixture rose in temperature in presence of the zinc-copper element and gave a very good yield of acetylene.

Roemer's researches

In 1886 Roemer,[2] working with the apparatus devised by Jungfleisch, found that he obtained a much increased yield of acetylene when the coal gas was charged with the vapours of sulphuric ether. He also observed that the gas prepared by acting upon copper acetylene by hydrochloric acid deposited during the night a dark film on the walls of the glass gasholder, and that this deposition was not accompanied by any change in volume. This deposit would probably be one of the poly-acetylenes discovered by Baeyer.

The discoveries of 1892

During the next few years there was a lull in the tide of acetylene researches, followed by the storm of activity which rendered 1892 the most important year in the history of the gas, and as a considerable amount of controversy has arisen with regard to the events of this period, it will be well to treat them at length.

The Electric Furnace

It was Sir Humphry Davy who first demonstrated the heat and light of the electric arc, and it was late in the seventies that Sir William Siemens inaugurated an entirely new era in experimental and metallurgical work by patenting his electrical furnace, in which the electrical energy could be converted into heat, thus yielding a temperature which had never been before available, and which has been estimated by Violle as approximating to 3,500° C. As gradually the utility of the electrical furnace came to be recognised, other patents were taken out, Bradley patenting a furnace

Temperature of the Electric Furnace

[1] *Compt. Rend.*, 113, 1054. [2] *Lieb. Ann.*, 233, 182.

in 1883, whilst Cowles took out his patents in 1885, and in 1886 patented a lining of lime and carbon for the furnace as being more refractory. Although these furnaces were used for making aluminium, large quantities of carbide of calcium were accidentally made by the action of the heat on the furnace lining, and during 1886 and 1887 the lads employed in the works used often to amuse themselves in the dinner hour by putting water on the old crucible linings and igniting the gas which was set free. Even before this date it was recognised and published by T. Sterry Hunt[1] that in the Cowles electric furnace the oxides, not only of the alkaline metals, but of calcium, magnesium, aluminium, silicon and boron, could be reduced in the presence of carbon and could be made to form alloys with other metals present, whilst with aluminium and other metals the crystalline compounds formed with carbon could be obtained, and, further, that silicon and the compound of silicon with carbon could be produced. Borchers also, in his treatise on electro-metallurgy published in 1891, says: "All the oxides are capable of being reduced by carbon heated by electricity," but makes no mention of calcium carbide.

Accidental production of Calcic Carbide in making Aluminium

Actions in the Electric Furnace

Borchers

It is clear, therefore, that as early as 1886 calcic carbide was made in the electric furnace, but its formation was merely accidental, and no commercial importance was attached to it.

Soon after this date Willson conceived the idea of reducing aluminium in the presence of copper to make aluminium bronze, and employed practically the same method as that used by Cowles; but as his attempts to make the bronze were not successful, he attempted to reduce magnesium and calcium to the metallic state, in order to utilise these metals for the reduction of alumina. It was in the spring of 1892 that he attempted to reduce lime by carbon, and he found that

The work of T. L. Willson

[1] *Trans. Amer. Inst. Min. Eng.*, xiv. 492.

The treatment of Lime and Carbon in the Electric Furnace

he obtained by this means a fused bath, the boiling of which caused the short circuiting of the electric arc, and, in order to prevent this spitting of the liquid and the unequal loading of the dynamo, which interfered seriously with the working of the machinery and water turbines, he added to it a layer of carbon, which prevented the splashing of the liquid against the sides of the electrode, the only portion of the liquid surface exposed being in the immediate path of the arc.

The Calcic Carbide made by Willson

It was in the May of 1892 that carbide was obtained by Willson in quantity, and samples were sent by him to various scientific friends in America, and in June, 1892, Venable[1] went to Spray to investigate the progress made by Willson in his aluminium process, and in writing of this visit says:—

"I found that Mr. Willson had attacked his problem from many different sides. Among other plans, he had conceived the idea of preparing some more positive element, like calcium, and making use of this to liberate aluminium from the oxide. In his efforts at producing calcium he had mixed lime with tar and other forms of carbon and treated these mixtures in his furnace. In this way he had produced a hard, crystalline mass, which disintegrated and crumbled on exposure to the air and gave rise to a violent evolution of a gas when brought in contact with water. This gas was inflammable, burning with a very smoky flame."

On September 16th, 1892, Willson sent specimens of his carbide to Lord Kelvin.

The letters which passed between Willson and Lord Kelvin have been published by Mr. Fraser,[2] who was Willson's patent solicitor, and are as follows:—

[1] *American Manufacturer*, Dec. 16th, 1898.
[2] *Progressive Age*, Feb. 1st, 1898, p. 51.

LETTER.

THOMAS L. WILLSON TO LORD KELVIN.

"SPRAY, N.C., *September* 16*th*, 1892.

"Lord Kelvin, Glasgow University, Glasgow, Scotland.

Correspondence between Lord Kelvin and T. L. Willson

"MY DEAR SIR,—

"It affords me very great pleasure to forward to you some calcic carbide made in my electric 'arc' furnace. This product is from the reduction of lime—calcic oxide—by carbon with the high heat of the electric 'arc,' and carbon has displaced the oxygen.

"The great affinity of the combined calcium for oxygen enables this material to decompose water rapidly, liberating hydrogen combined with carbon, which, upon ignition, burns, the hydrogen uniting with the oxygen of the air, liberating the excess of carbon, which floats in the air. This material greatly interests scientific men here, and I hope will prove of interest to you.

"Perhaps, with your laboratory facilities, you may be able to obtain metallic calcium from this composition. If you desire any further information in regard to this material, I shall be pleased to place what little knowledge I have of it at your disposal. Hoping that the two jars sent you to-day by express may reach you in safety. I remain,

"Yours with best wishes,

"(Signed) THOMAS L. WILLSON."

LORD KELVIN'S LETTER IN REPLY.

"THE UNIVERSITY, GLASGOW, *October* 3*rd*, 1892.

"DEAR SIR,—

"I have seen and tried the calcium carbide—only, however, so far as throwing it into water and setting fire to the gas which comes off. It seems to me a most

interesting substance, and I thank you very much for sending it to me.

"Yours very truly,

"(Signed) KELVIN.

"Thomas L. Willson, Esq."

Mr. Fraser[1] also publishes another letter written to him by Willson in May, 1892, with regard to the patent Fraser was then drafting, from which the following is an extract:—

"*May* 19*th*, 1892.

Letter from Willson to his patent solicitor

"I want some of my 'claims' to cover the production of carbide of aluminium and calcium carbide and all the other carbides.

"Calcium carbide is one of the most curious and interesting of the carbides. Like metallic sodium and potassium, it has the power to decompose water and oxidizes in the air, so has to be kept covered with oil —kerosene—or in air-tight vessels. It is made by heating lime CaO and carbon. The best result is obtained by infusing the lime in tar, and then subjecting to the electric arc."

These letters make it perfectly clear that Willson was making calcium carbide by the direct fusion of lime and carbon in the early part of 1892, and having finished his experimental investigation on August 9th, 1892, Willson filed an application for a United States patent for electric smelting, principally of aluminium, in which he said he proposed to apply the invention "for the production of refractory compounds or ores of metals, not necessarily for the production of the metals themselves, but for the production of other compounds thereof. For example, I have already employed it for reducing calcium

Willson's patent of Feb. 21st. 1893

[1] *Progressive Age*, Feb. 1st, 1898, p. 51.

oxide and producing calcium carbide." This patent was issued February 21st, 1893, No. 492,377. This issue became the first public publication mentioning Willson's invention of calcium carbide.

Maquenne makes Barium Carbide and decomposes it with water to form Acetylene

In May, 1892, Maquenne[1] made barium carbide by heating barium nitride with carbon in a current of nitrogen, and found that the product so obtained was decomposed by water with evolution of acetylene and hydrogen. Later in the same year, October 17th,[2] he described a new method for the preparation of the gas. Resuming the researches of Winkler[3] on the result of heating mixtures of magnesium with carbonates of the alkaline earths, which Winkler believed resulted in the reaction—

$$CaCO_3 + 3Mg = 3MgO + Ca + C,$$

The formation of Acetylene from Barium Carbide

and the residue from which, he said, gave off hydrogen having a disagreeable odour when acted on by water. Maquenne fused together 26 gr. of barium carbonate, 10·5 gr. of magnesium powder and 4 gr. of retort carbon, when an intense reaction took place. The residue consisted of magnesium oxide and 38 per cent. of barium carbide, a little carbon and traces of cyanides formed by the atmospheric nitrogen—

$$BaCO_3 + 3Mg + C = BaC_2 + 3MgO.$$

The product formed was very light, of a grey colour, and very porous, completely amorphous and unalterable in dry air. One hundred grammes decomposed in a dripping apparatus produce 5,200 to 5,400 cc. of gas, consisting of acetylene with 2 to 3 per cent. of hydrogen without any other hydrocarbon.

$$BaC_2 + 2H_2O = Ba(OH)_2 + C_2H_2.$$

Moissan's first mention of Calcium Carbide, Dec. 12th, 1892

On December 12th, 1892, Henri Moissan,[4] whose name will always rank high amongst the illustrious

[1] *Bull. Soc. Chim.*, 7, 370.
[2] *Ibid.*, 7, 756–773.
[3] *Berl. Ber.*, 23, 2645.
[4] *Compt. Rend.*, 115, 1031.

band of French chemists who have done so much for science, read a paper before the French Academy of Science, in which he describes his electrical furnace and the work which he had done in reducing the metals of the alkaline earths, and in this paper he says: "At this temperature—3,000° C.—the carbon rapidly reduces the oxide of calcium, and the metal is liberated in abundance. It easily unites with the carbon of the electrodes and forms a carburet of calcium liquid at a red heat, which it is easy to separate."

Travers makes Calcium Carbide, 1893

In 1893 W. Travers[1] melted 45 gr. of sodium with an intimate mixture of calcium chloride and retort carbon, using an iron crucible and continuing the heating for half an hour. The products of the reaction consisted of sodium chloride, calcium carbide and carbon, nearly 16 per cent. being carbide. One hundred gr. of this product yielded 4 to 5 litres of acetylene when acted on by water.

Moissan describes Crystalline Calcium Carbide, 1894

On March 5th, 1894, Moissan[2] brought another paper before the Academy of Sciences, in which he described the preparation of crystallised carbide of calcium, made by fusing together an intimate mixture of 120 gr. of lime made from marble and 70 gr. of sugar charcoal in the electric furnace, using a current of 350 ampères and 70 volts for from 15 to 20 minutes, 120 to 150 gr. of calcium carbide being obtained. In the introduction to this paper he mentioned the methods used by Woehler and Maquenne in preparing calcium carbide, and also noticed the work of Winkler. He described the carbide as a black, well-crystallised mass, having a specific gravity of 2·22 at 18° C., and obtained for it the following analytical figures:—

The analysis of Calcium Carbide

	I.	II.	III.	IV.	Calculated.
Calcium . .	62·7	62·1	61·7	62·0	62·5
Carbon . .	37·3	37·8			37·5

[1] *Proc. Chem. Soc.*, 9, 15. [2] *Compt. Rend.*, 118, 501.

He therefore concluded that the formula was CaC_2. He also analysed the gas liberated by its action upon water, and found it to be nearly pure acetylene.

Metallic Carbides

Later[1] he described the preparation of the carbides of barium and strontium and their properties. He found that they were analogous to the carbide of calcium, and decomposed water yielding acetylene in the same way.

Manufacture of Calcium Carbide at Spray

Whilst M. Moissan was conducting his classical researches on chemical actions at high temperatures, using for his experimental work his small electrical furnace, working at about 350 ampères and 70 volts, Willson had been busily employed during 1892 and 1893 in working and continuing his experiments on the manufacture of carbide on a commercial scale at the works at Spray, in North Carolina, in which a dynamo, worked by water power and generating a current of 2,000 ampères at 25 volts, was employed.

The question of priority between Moissan and Willson

There is not the slightest doubt that the work of Moissan and Willson was entirely independent, and that the Canadian experimentalist at Spray and the brilliant Parisian savant had never even heard of each other, much less of the work they were respectively doing, until certainly after the publication of Moissan's paper in 1894; and it is also perfectly clear that up to the end of 1892 it was Willson, and Willson only, who had made calcium carbide on anything like a large scale, and nothing would ever have been heard of this material on a commercial scale had it not been that he, in attempting to get capital invested in his process, came across several men of sound practical knowledge, whose business instincts led them to grasp the possibilities of carbide and acetylene, and no sooner had these commercial possibilities been noised abroad than others began to try and make capital from them. In France, on February 9th, 1894, Bullier

Bullier's patent

[1] *Compt. Rend.*, 118, 683.

applied for a patent for the preparation of the carbides of the alkaline earths based on Moissan's researches. M. Moissan himself has never claimed priority in the manufacture of commercial carbide, and, indeed, whilst lecturing before the New York Section of the Society of Chemical Industry on October 26th, 1896, he distinctly stated that the credit of the first production of calcium carbide on a commercial scale was due to Willson, and the industrial utilisation of acetylene belonged to the Americans.[1]

Moissan admits Willson's priority as regards commercial Acetylene

Borchers' claims

Borchers is also a claimant for the honour of priority in the preparation of calcium carbide, basing his claim on the statement made by him in the first edition of his book on *Electro-Metallurgy*, published in 1891, that "all the oxides are capable of being reduced by carbon heated by electricity." In the second edition of his textbook published in 1896[2] he says: "During the years 1880 to 1890 I succeeded in reducing, by electrically-heated carbon, all the metallic oxides which had not been reduced up to that date.[3] When using an excess of carbon, residues rich in carbon were produced, but to these at that period I paid but little attention, because I was looking for methods for preparing the technically useful metals." In 1895 also he states[4] that during the eighties he succeeded in reducing all oxides which had not before been reduced, and that after his publication in the year 1891 everybody is free to prepare metallic carbides by electrical heating mixtures of the respective metal with carbon, and is free to use his (Borchers') or Siemens', or any other electrical furnace.

Borchers' statements in 1896

In an address to the meeting of the German Electro-

[1] *Schweitzer Ztsh. Calc. Sc.*, 2, 69.

[2] *Electro-Metallurgy*, 2nd edition, 1896, 84.

[3] Deville and Debray (*Jahr. Ber.*, 1859, 256) state that carbon and lime heated in their oxy-hydrogen furnace, react, with reduction of the lime.

[4] *Zeitsch. f. Electro-Chem.*, 2, 7.

Chemical Society at Frankfort in June, 1895,[1] he says: "As I have before stated, the reactions taking place in making calcium carbide by the process claimed by Moissan and Willson may be represented by

1. $CaO + C = Ca + CO$
2. $Ca + 2C = CaC2$

Borchers criticises Moissan and Willson

The second reaction was discovered by Woehler. The first reaction has been published in the first edition of my *Electro-Metallurgy*, 1891, in which, after describing the furnace shown to-day at this meeting, I pointed out that by means of it all oxides not yet reduced can be reduced.

"At that time I also obtained calcium carbide, to which I drew no attention, as I was seeking for the metals. At the present time Moissan reduces these refractory oxides, one after the other, in an electric furnace, and makes out each of his reactions as if they were totally unknown, and reports on them to the French Academy. I have no doubt that Moissan makes his publication in perfectly good faith, and I will not deny Willson's merit in having started the commercial use of calcium carbide in connection with a cheap method of its preparation, but there is no doubt that the true method of preparing calcium carbide was first shown in Germany by German chemists."

Still later, Borchers,[2] in speaking of Bullier's patent, says: "There is no disputing the fact that my publications prove that, long before Moissan and Willson, I made calcium carbide by the reduction of lime with electrically heated carbon.

"I freely admitted in my lectures that, as I was seeking for metals, I did not recognise the value of the carbide and the method of its preparation."

Conclusions as to priority

In considering the question of priority, it must be clearly borne in mind that the point at issue is not "Who discovered calcium carbide and its power of de-

[1] *Zeitsch. f. Electro-Chem.*, 2, 164. [2] *Ibid.*, 4, 93.

composing water with evolution of acetylene ?" because the honour of that discovery is undoubtedly due to the great German chemist Woehler, but "who was it who first made calcium carbide in such a way as to bring the acetylene generated from it within the range of commercial utility, and at the same time recognised the possibilities of the process?"

The claim of Borchers may at once be dismissed as having no reasonable foundation, and, indeed, being nothing more than an ineffectual and scarcely creditable wail at having missed an important and lucrative discovery. The whole scientific world would rejoice if it were possible to accord to Moissan, "the king of experimental savants," the honour of having given this new process to the commercial world. His results were obtained as factors in a magnificent research, every step in which was logically worked out and verified; a research which will ever stand out as a scientific classic. But the fact remains that he only attained and published the discovery of the direct formation of calcium carbide in the electric furnace, to find that his work had been forestalled by a few months by the chance observation of an engineer, who, although devoid of chemical knowledge, yet had sufficient practical acumen to grasp the commercial importance of the discovery; and any one who, with a mind free from prejudice, reads the evidence on this subject is forced to the conclusion that the world owes "commercial acetylene" to the Canadian engineer Willson and the shrewd business men who supported him.

Bullier's claims

Bullier occupies a most unenviable position in the affair. In his patent he stands forth as the inventor of the process which "consists essentially in heating in an electric furnace—such as a Moissan furnace, for example—a mixture of carbon with the oxide of the earth metal or alkali metal to be carburised,"[1] and

[1] English Patent No. 2820 (1895).

which is manifestly the process described by Moissan in the *Comptes Rendus*, and it is conceivable that Bullier, having worked with Moissan, and the latter not desiring to patent the discovery, allowed Bullier to do so, although it is strange that Moissan should make no mention of the collaboration in his paper.

In 1896 Willson applied for a special Act of Parliament to antedate his English patent, which by an error had been filed with the date of the English application instead of the American application. The granting of the Act was opposed by Bullier and others, and in his petition Bullier says:[1] "Your petitioner claims to be the first discoverer of the process referred to in the preamble of the Bill." The preamble alluded to gives the process as an invention which consisted in first treating lime with carbonaceous matter in an electric furnace to produce calcium carbide; and, secondly, in mutually decomposing such calcium carbide with water to liberate a hydrocarbon gas known as acetylene.

During the hearing of the evidence Bullier's counsel distinctly suggested that Moissan, in his celebrated paper of March 5th, 1894,[2] had been merely communicating Bullier's discoveries to the Académie des Sciences, a suggestion probably made without Bullier's sanction, and which the clear priority of Willson robs of any undue significance.

In 1895 the commercial career of acetylene may be looked upon as being thoroughly established, and many observations were made as to its behaviour in everyday use, but these now became so numerous that it would serve no useful purpose to continue the enumeration of them in historical order, and in the following chapters the gist of these results will be collected together in discussing the various physical and chemical properties of acetylene.

[1] Par. G. Bullier's petition. [2] *Compt. Rend.*, 118, 501.

CHAPTER II

THE PREPARATION OF ACETYLENE

A.—The Formation of Acetylene by the Direct Union of its Constituents

Analysis

THE two methods most used in chemical science for tracing the changes taking place in matter and determining the composition of bodies are, firstly, breaking up compounds into their ultimate constituents—a process which is called "analysis"; and, secondly, by building up the compound from the elementary matter which forms it, a process to which the name of "synthesis" is given.

Synthesis

Most inorganic compounds can be synthetically produced from elementary matter, but in the so-called organic chemistry it is not so easy to employ such constructive methods for the formation of compounds, and up to the end of the first quarter of this century it was supposed that organic bodies were only produced as the result of animal and vegetable life, and that their formation was due to the so-called "vital force" which was credited with governing all changes taking place in living organisms. In 1828, Woehler showed that urea could be formed from cyanate of ammonium, whilst later on Fownes made cyanogen by the direct combination of carbon and nitrogen, these two discoveries, taken together, proving the possibility of forming an organic product from inorganic materials; and after this point had been reached,

Synthesis of Urea by Woehler

The synthesis of organic compounds

and the possibility of applying synthetic methods to the production of organic bodies had been demonstrated, compound after compound was built up without the aid of either vegetable or animal life, and the barrier between inorganic and organic chemistry finally broken down.

The synthesis of Acetylene by Berthelot, 1862

Certainly one of the most important achievements in synthetical chemistry was the discovery by the great French savant, Berthelot, that acetylene could be directly built up from its elements under the influence of the electric arc, which he experimentally

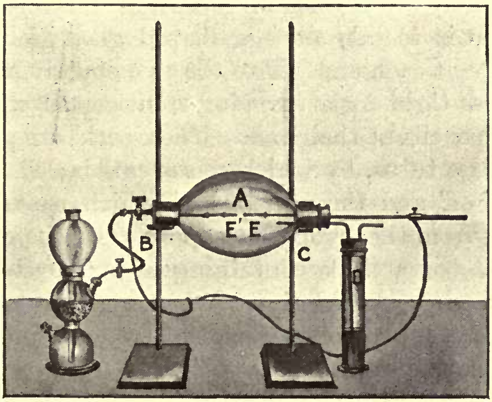


Fig. 1.

showed to be the case in 1862.[1] The apparatus which he employed is shown in Fig. 1.

Apparatus used

It consists of an egg-shaped glass globe A, with a tubulure B at one end, and at the other an opening C, closed by a cork carrying a tube leading to the bottom of the cylinder D, and also a metallic conductor, which slides easily in the cork and terminates in the carbon E, so that an arc can be struck with the carbon E′E which is in metallic contact with the tubulure B.

[1] *Compt. Rend.*, 54, 640.

Having driven all air out of the glass egg by a rapid current of hydrogen, which was allowed to pass for at least a quarter of an hour, he brought the two poles together and struck an electric arc, using for the purpose a battery of 50 Bunsen cells. Under these conditions he found that 10 to 12 cc. of acetylene were produced per minute, a very fair proportion, considering the smallness of the arc. The poles used should be formed from retort carbon or graphite, which give a better yield of acetylene than any other form of carbon, charcoal being the worst substance to use for this purpose.[1]

Carbons for synthesis of Acetylene

To show Berthelot's experiment for lectures

The simplest method of repeating this historic experiment is to take an egg-shaped glass globe with a tubulure at each end. Into the two opposite necks are fitted gas-tight corks carrying stout copper wires with carbon pencils at their ends. These corks are also fitted with glass tubes, by which gases can be led in or aspirated off, and through one of which passes a tube leading from the hydrogen supply. To the exit tube is connected a flask, containing an ammoniacal solution of cuprous chloride, and connected with two Erlenmeyer absorbing vessels, also containing some of the copper solution.

Method of conducting the experiment

Hydrogen is passed through the apparatus for some time in order to drive out the air, and then the carbons are brought together and the arc struck, a current of about 10 to 15 ampères being employed. The acetylene so produced is carried into the flasks containing the copper solution, and is there absorbed, forming the red copper acetylene.

Preparation of the Cuprous Chloride

The ammoniacal solution of cuprous chloride is best prepared by passing sulphur dioxide through a strong solution of cupric chloride, until the solution has entirely lost its green colour. The cuprous chloride meanwhile precipitates, and can be collected on a

[1] Berthelot, *Compt. Rend.*, 54, 1042.

filter, washed with acetic acid, and dried. A small quantity of this is then dissolved in a little strong ammonia when wanted and the solution diluted with water.

The solution for absorption of the Acetylene

The cuprous chloride may also be prepared by dissolving 250 parts by weight of crystallized copper sulphate and 117 of sodium chloride in water, then passing a current of sulphur dioxide through the solution until it is decolorized and cuprous chloride precipitated.

Acetylene both formed and decomposed by the electric arc

It is manifest that no very great percentage of acetylene can be formed by this process, as acetylene being decomposed by heat into its constituents once more, there will be a continual formation and decomposition of acetylene, which after a time will probably establish a balance. This point has been to a certain extent studied by Bone and Jerdan,[1] who came to the conclusion "that when the electric arc is passed between carbon terminals in an atmosphere of hydrogen, acetylene and methane are both produced. Further, that the rate of formation of these two gases is fairly rapid during the first fifteen minutes of the experiment, after which the rate falls, and finally, after about half an hour, a state of equilibrium between the hydrogen, acetylene, and methane is attained. This equilibrium depends to some extent on the voltage employed."

Bone and Jerdan's experiments

Result of experiment

Condition of experiment

The electric arc was formed between terminals of purified gas carbon in an atmosphere of dry hydrogen contained in a glass globe standing in a trough over mercury. The arc was maintained in hydrogen for an hour or more, and samples of the gas were drawn off at the end of 5, 15, 30, 45, etc., minutes in each experiment. These were afterwards analysed in a modification of the McLeod gas analysis apparatus.

Analysis of the products

The gases almost always contained small amounts

[1] *Proc. Chem. Soc.*, 1896.

of hydrocyanic acid, due no doubt to the presence of a little nitrogen in the hydrogen employed. Acetylene was always present in considerable quantities, and in addition to this and any other unsaturated hydrocarbon, appreciable quantities of methane were found.

Synthesis of Methane

The same authors, at an earlier date,[1] found that they could produce methane by passing a slow current of hydrogen, free from hydrocarbon impurities, through purified carbon heated to bright redness in a porcelain tube placed inside a Fletcher's injector furnace.

Equilibrium of products

These results led to the inference that methane and acetylene could both be synthesized and decomposed by the electric arc, and that if the arc be passed long enough through these gases, a state of equilibrium would be arrived at. This conclusion was fully borne out by subsequent experiments, in which pure acetylene or methane was subjected to the action of the electric arc passed between carbon terminals in the same apparatus as that employed in the experiments with hydrogen.

Separation of Carbon

Both methane and acetylene are easily decomposed by the electric arc; during the first ten minutes of the experiment the gas, methane, or acetylene, as the case might be, was very rapidly resolved into its constituents—large flakes of carbon were formed in the neighbourhood of the terminals, and fell on the surface of the mercury below; the gas in the globe underwent a great increase in volume, much greater than could be accounted for by the mere expansion of the gas by the heat of the arc; a smoky flame rose from the terminals and filled the upper part of the globe. At the end of about ten minutes this extraordinary appearance subsided, after which the arc presented the same appearance as in the case of the hydrogen experiments. After the arc had passed for an hour the experiment

[1] *Proc. Chem. Soc.*, 162, 61.

was stopped. Samples of the gas were then collected and subsequently analysed.

The principal product in each case was hydrogen, with about 9 per cent. of acetylene, and small quantities of methane, nitrogen, and hydrocyanic acid. In the experiment with acetylene a minute quantity of naphthalene was also formed.

Dewar's experiments on the synthesis of Acetylene

In 1880, Dewar[1] published some very beautiful researches on the electric arc, and "in order to ascertain whether the formation of hydrocyanic acid and acetylene in the arc was really due to transformations induced by some occult power located in the arc, or

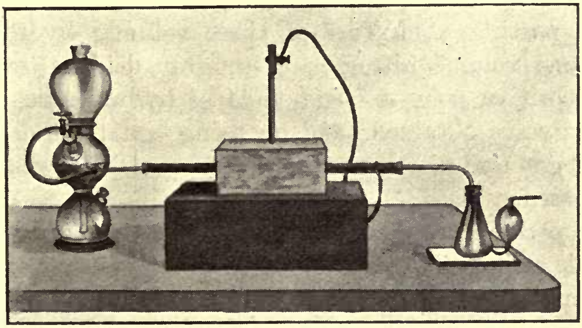


Fig. 2.

was simply the result of the high temperature attained by the carbons, a series of experiments was made in carbon tubes, the arc being merely used as a means of heating."

The following is the method of arranging the arc for this experiment:

Method of making the experiment

A block of limestone about fourteen centimetres long by eight thick was drilled horizontally, as shown in Fig. 2, another hole being drilled so as to meet it in the centre of the mass.

[1] *Proc. Royal Soc.*, 30, 88.

Arrangement of the Carbons

A drilled purified carbon was placed in the horizontal channel and made the positive pole, the negative pole being a solid rod of carbon passing through the vertical aperture. Gases were passed through the positive carbon, and were thus subjected to the intense heat of the walls of the tube, the arc passing outside.

The walls of the positive carbon burnt through with great rapidity, not lasting, as a rule, more than fifteen minutes. This action could only be prevented by using thicker carbons, and, consequently, reducing considerably the intensity of the heat.

The porosity of the carbons, which allowed a constant diffusion of gases through their walls, was another source of difficulty.

Formation of Hydrocyanic Acid

On passing a mixture of three volumes hydrogen and one volume nitrogen, thoroughly dried, through the positive pole, a large yield of hydrocyanic acid was always obtained; and on using equal volumes of hydrogen and nitrogen, the quantity was, if anything, increased.

Formation of Acetylene

Pure dry hydrogen by itself gave a trace of hydrocyanic acid and a considerable quantity of acetylene.

Pure dry air gave no hydrocyanic acid or acetylene; moist air, on the contrary, giving abundance of the former, but only a trace of the latter.

Influence of rate of flow on the product

The yield in all these experiments altered considerably with the rate at which the gases were passed, a quick stream always producing more than a slow one, unless when oxygen was present, and it is manifest from these researches that the direct combination of carbon and hydrogen to form acetylene is simply the result of the high temperature attained in the electric arc.

Temperature needed for synthesis of Acetylene

This result has never been observed at temperatures short of that obtained in the electric arc, and Berthelot [1] has shown that induction sparks passed between

[1] *Compt. Rend.*, 54, 640; *ibid.*, 54, 1042.

purified carbons in an atmosphere of hydrogen does not yield acetylene.

B.—The Preparation of Acetylene by the Incomplete Combustion of Gases containing Hydrogen and Carbon.

It was first shown by Berthelot[1] in 1866 that when a cylinder containing coal gas or ethylene is held in a nearly horizontal position, and the gas is ignited, the flame as it runs back into the cylinder being dependent on the air sucked in for its combustion, is not completely consumed, and acetylene is found amongst the products of incomplete combustion.

Acetylene formed by incomplete combustion

The best way of exhibiting this method of producing acetylene is to take a glass gas cylinder of from 300 to 500 cubic centimetres capacity, and to place in it 6 to 8 cc. of ether, and about the same volume of ammoniacal cuprous chloride. On now holding the cylinder in a sloping position, and applying a light, the vapour of ether ignites at the mouth of the cylinder and gradually burns down into it; and the amount of air being insufficient for the complete combustion of the ether vapour, the copper solution rapidly changes colour; and if the cylinder be rotated in a nearly horizontal position, the red copper acetylene compound makes its appearance in abundance.

Method of showing the experiment

Benzene, petroleum spirit, or any other highly volatile liquid hydrocarbons, may be substituted for the ether, but the most striking results are obtained with the latter.

Other Hydrocarbons that may be used

The first idea of utilising this method for the production of pure acetylene is due to McLeod,[2] who in 1866 exhibited before the Chemical Society a mode of forming copper acetylene in considerable quantity

McLeod's method of making Acetylene

[1] *Compt. Rend.*, 62, 44. [2] *Journ. Chem. Soc.* (2) 4, 151.

by a modification of the process first indicated by M. Berthelot. The apparatus was simply one in which the inverted combustion of oxygen in coal gas was usually shown as a lecture illustration, with an appropriate receptacle charged with ammonio-subchloride of copper, through which the products of combustion were passed. A gasometer full of marsh gas—prepared by heating acetate of sodium with soda lime—was in

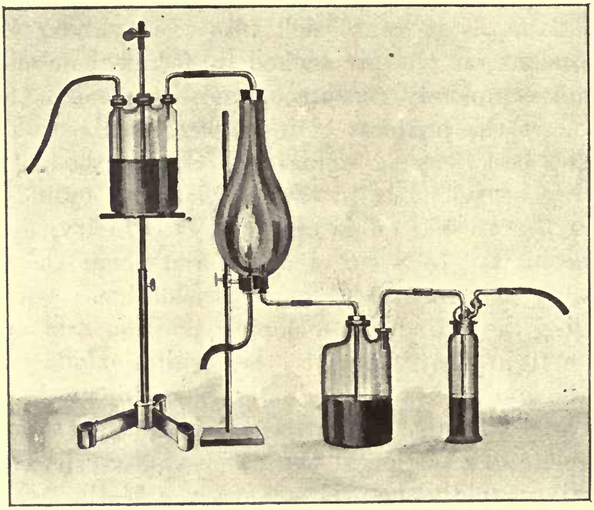


Fig. 3.

this instance made use of, and, to make the proof absolute, the gas was first passed through a preliminary washing-bottle containing the same copper solution. A red precipitate of the substance in question was quickly formed, and McLeod stated that in the apparatus exhibited he had prepared in an hour a gramme or more of the copper acetylene. The copper compound so produced could be then decomposed by hydrochloric acid, and the acetylene liberated from it.

Purification of the Acetylene from other products of the combustion

In the following year, 1867, Rieth[1] showed that when a Bunsen-burner flame strikes back and burns at the nipple of the gas injector, the combustion is so checked by the limitation of the air supply that acetylene is produced in abundance, and by aspirating the products of incomplete combustion through an ammoniacal cuprous chloride solution he succeeded in obtaining nearly 100 grammes of the copper acetylene compound.

Rieth shows that Acetylene is formed by the incomplete combustion taking place in an atmospheric burner that has lighted back

This method of preparation was, up to the date of

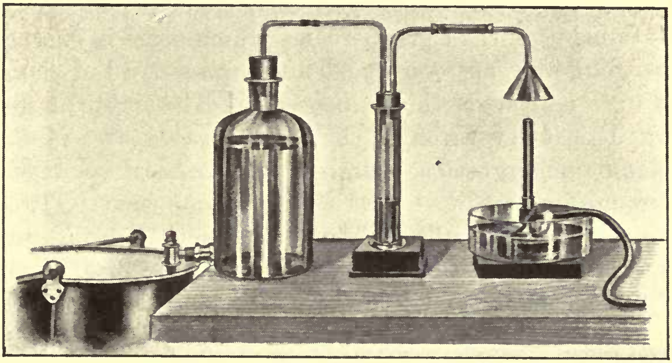


FIG. 4.

the discovery of calcium carbide, one of those most widely used.

Lecture apparatus

The ordinary method of procedure is to use an apparatus of the form shown in Fig. 4, which consists of an ordinary Bunsen burner that has been lighted at the bottom, and which stands on a dish of water in order to prevent the base from becoming red-hot, whilst broad cotton wick is passed from the water over the metal tube between the base and the tubing, and also over the end of the tubing itself, in order to prevent fusion by the conducted heat. Over the

[1] *Zeit. f. Chem.*, 2, 598.

mouth of the Bunsen is placed an inverted funnel, which is connected with a cylinder and absorbing flasks containing either ammoniacal cuprous chloride or an ammoniacal solution of silver nitrate, and the products of incomplete combustion from the burner are drawn at a fairly rapid rate through the series of absorbing vessels by an aspirator, the acetylene being afterwards obtained from the metallic compound by decomposition with hydrochloric acid.

Generation of the absorbed Acetylene

Acetylene present in the interior of all Hydro-carbon flames

In a coal-gas flame burning in air acetylene is always formed in the interior of the flame itself, as when the hydrocarbon gas leaves the jet at which it is being burnt those portions which come in contact with the air are consumed and form a wall of flame which surrounds the issuing gas. The unburnt gas in its passage through the lower heated area of the flame undergoes a number of chemical changes, brought about by the action of radiant heat emitted by the flame walls, the principal action being the conversion of the heavier hydrocarbons into acetylene, methane, and hydrogen.

Formation of Acetylene in the flame

Acetylene decomposes to Carbon and Hydrogen in an ordinary luminous flame

The acetylene so formed is decomposed in the hottest part of the flame—which is just below the outer zone of non-luminous combustion — and yields the carbon particles which render the flame luminous, and which, together with carbon monoxide and hydrogen generated in the flame and any residual hydrocarbons, undergo complete combustion in the outer zone of the flame.

If, however, a jet of air is burnt in an atmosphere of coal gas, the conditions are reversed, and the acetylene produced by the incomplete combustion of the hydrocarbons, and by the heat of the combination, is formed on the outer fringe of the flame, and escapes undecomposed with the residual coal gas.

Inverted combustion

McLeod having shown that the combustion of oxygen in methane yielded acetylene, and Rieth

having drawn attention to the formation of the gas during the checked combustion of coal gas when an atmospheric burner flashes back and burns at the bottom, it was manifest that if a simple apparatus were constructed for the combustion of a jet of air

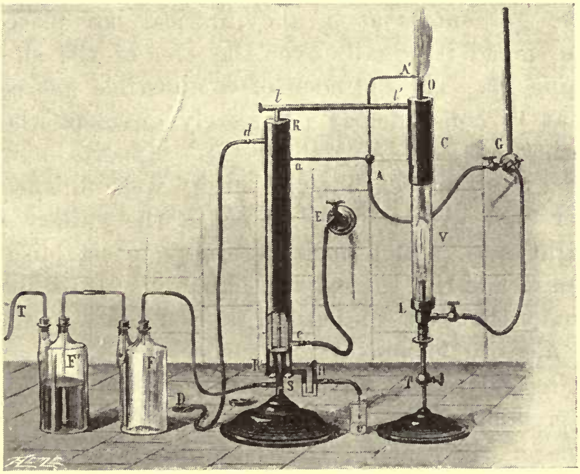


FIG. 5.

in an atmosphere of coal gas, a good yield of acetylene would probably be obtained, and in 1880 Jungfleisch[1] devised the apparatus shown in Fig. 5.

Jungfleisch's apparatus

This apparatus consists of two parts: one, the burner in which the incomplete combustion is carried on; the other, a series of vessels in which the acetylene is separated from the other products of the combustion.

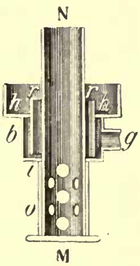


FIG. 6.

The essential feature of the burner is shown in Fig. 6.

Jungfleisch burner

It is composed of a central tube MN, pierced at the lower end by a number of small holes, which open or close by

[1] *Manipulations de Chimie*, Paris, 1886, p. 744.

means of a movable ring *oi*, perforated in a similar manner. This tube serves for the introduction of air, the influx of which is regulated by the perforated ring. In the interior of MN the upright metal partitions prevent the air from rotating—a movement which would result in an unsteady flame.

Arrangement of the apparatus

The gas enters at *g*, a cylindrical box placed so as to spread it equally over the area of the circular opening *rr*. The cylinder of combustible gas escaping at *rr* consequently completely envelops the air entering at N. A gallery HH supports a glass chimney V, 30 centimetres high, well finished at either end. A few drops of oil in the gallery form a tight seal, which it is necessary to establish between it and the base of the chimney. It is in this chimney that the combustion takes place. A sliding foot *p* easily lowers or raises the burner.

Condensation of the water vapour formed

A second metal portion of the apparatus receives the products of combustion, which are carried up by means of a cylinder. This is formed of an upright brass tube C, the lower portion of which overlaps the upper portion of the chimney N, an air-tight joint being formed by the chimney fitting into a circular space formed between the outer tube C and an inner one of smaller diameter to which it is fixed. The tube C communicates at the top, by means of a small metal pipe H, with a brass refrigerator RR′, which cools the gas and condenses the water vapour drawn off from it. The refrigerator may consist of several tubes, as shown in the figure, thus possessing a large cooling surface; or it may be made with only one tube, which must be slightly larger. It is cooled by a current of water entering at E *e*, and escaping at *d* D. The lower portion R′, consists of a closed chamber, into which both the condensed liquid and the cooled gas enter. By means of proper adjustments the former escapes at V through a bent tube H, thus

forming a hydraulic seal for the gas, the bend having previously been filled with water, whilst the gases are drawn off by a pipe fixed to the tube S, which supports the refrigerator.

At O, above the burner, is a small metallic chimney, by which the products of combustion escape when the cylinder, of which mention is made further on, is not in use. These gases are fairly combustible, and have to be kept constantly burning by means of a small gas burner A′, fed from *g* A, and joined at (*a*) to one of the cold portions of the apparatus. To complete the apparatus *oi* joins the tube S, by an india-rubber connection, to a series of two or three wash bottles F′, which contain the ammoniacal copper reagent.

Absorbing apparatus

Any variation of pressure caused by the gas bubbling through the wash bottles is nullified by placing between S and the first bottle F′ a similar vessel F, which is filled by the gas.

Variation of pressure

The suction throughout the apparatus is produced at T by a rotary pump capable of passing at least 1 cubic metre per hour. The ordinary air pump in general use in laboratories only passes 200 to 300 litres per hour, and is not capable of working the apparatus.

To start the apparatus, the burner is first lighted. To do this, the sliding stand *p′* is lowered and the chimney removed, the ring *oi* being so adjusted as to allow only a small quantity of air to enter; the burner is lighted, and the chimney replaced in the oiled gallery, the apparatus being then raised to its former position. A small flame is produced at N, and the surplus gas escapes at O with the products of combustion. The gas is lit at A, the supply of gas and air being at the same time increased in the burner L. A large flame soon appears at O, and the pump can then be started, so as to produce a rapid stream

Starting the apparatus

of bubbles in F′, and the burner can next be regulated.

Production of the flame

The essential point is to maintain at the surface of the air at V a regular flame, clearly outlined and surrounded on all sides by burning gas, and to allow no trace of oxygen to escape; in other words, to produce at V a fixed flame. With the pump in good working order, the height of the flame will decrease with too great a supply of gas, whilst the flame at O will be luminous; on the other hand, with the air in excess, the flame will rise, expand towards the top, and develop a reddish tint, whilst non-combustible gases escape at O. The exact adjustment for obtaining the largest yield of acetylene can only be secured after many trials, observing the above precautions.

Appearance of the flame

The correct flame at O is of a purple tint, easily extinguishable, and limited in height to a few centimetres. When the cylinder has been regulated, it will not again want adjusting.

The interior flame is yellow, long, and slightly smoky. The gas evolved contains about 3 per cent. of acetylene, and up to a certain point the yield increases with the rapidity of the suction.

It is necessary to maintain a constant flame at O, because by the appearance of the flame the apparatus can be regulated, and also because carbonic oxide and cyanide of ammonium being amongst the products of incomplete combustion, these latter must not be allowed to escape into the air; and, again, the flame at O indicates that an excess of pressure exists at V, and that air cannot be drawn up between the chimney and the cylinder.

Even with a rapid flow of gas three vessels, as at F′, are usually sufficient to almost entirely absorb the acetylene. When the solution in the first bottle ceases to act, the bottle is removed—the two others being connected up—and its contents emptied, fresh

solution being then placed in it. It is now connected up behind the other two. During this operation the connection with the pump must be cut off in order to avoid air entering the copper solution, and combustion continues at o, the gas escaping in a long flame. Provided the regulation of the burner has not been interfered with, on connecting up the wash bottles the apparatus will work as before.

Management of the absorbing bottles

With this apparatus considerable quantities of copper acetylide can be obtained in a short time, and this requires to be kept as much as possible from contact with the air and thoroughly washed.

Simple modification of the Jungfleisch apparatus

The Jungfleisch apparatus is costly, and somewhat complex, but the same action can be easily shown as follows: an ordinary paraffin or Argand lamp chimney is fitted at the bottom with a cork, through which pass two glass tubes, Fig. 7. One tube passes through the centre of the cork, and is about 10 centimetres long, with a bore of 1 centimetre; the other tube is bent at right angles, and is of smaller bore, and is connected to the gas supply. A piece of asbestos card about 6 or 7 centimetres square, and with a round hole in the centre about $1\frac{1}{2}$ centimetres in diameter, is placed on top of the chimney. A stream of coal gas is passed through the apparatus, the hole in the asbestos being loosely closed by a covering of card or mica. After a few moments the excess of gas escapes by the central tube, and is then lighted, the hole at the top being at the same time uncovered. The flame then passes up the tube, drawing air in after it, which continues to burn with a faintly luminous flame in the surrounding coal gas. The excess of coal gas escaping from the hole may be ignited, so that two flames are produced—the one a flame of air burning in coal gas, and the other a flame of coal gas burning in air. A glass tube bent at right angles is introduced into the chimney through the hole in the

General arrangement of apparatus

asbestos card, and is connected at the other end to the absorbing vessel, which is in connection with any convenient aspirating apparatus, such as a Bunsen's pump or an aspirating bottle. The gaseous contents of the lamp chimney are in this way made to bubble through copper solution where the acetylene is absorbed.

Preparation of Copper Acetylene with the apparatus

With this apparatus large quantities of the copper compound may be prepared, the copper solution being contained in a large Woulfe's bottle, and the operation allowed to continue for some hours. Two or three tubes, leading to as many absorbing bottles, may at the same time be inserted into the chimney, so long as the united volume of gas which they draw away is not greater than the volume of coal gas which is passing through the apparatus, in which case air would be sucked down through the hole in the card, and, passing through the copper solution, would oxidize it. It is easy to ascertain whether there is an excess of coal gas escaping either by applying a light, or, better, by bringing a taper, which has been lighted and then blown out and is still smoking, near to the hole, and observing whether the smoke is carried up or drawn into the chimney.

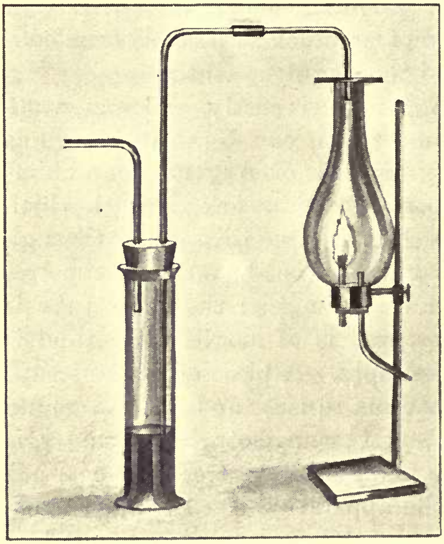


Fig. 7.

Yield of Acetylene increased by the presence of Ether vapour

The production of acetylene by the incomplete combustion of coal gas in any of these forms of apparatus may be greatly increased by allowing the coal gas to pass through cotton wool moistened with sulphuric ether, contained in a wash bottle or in a wide tube, the influence of the presence of the ether vapour having been noticed by Roemer[1] in 1886.

Impurities in Acetylene formed by the decomposition of Metallic Acetylenes with Hydrochloric Acid

It is to be noted that in all cases where acetylene is first converted into copper acetylene, and this compound then decomposed by hydrochloric acid, the gas evolved contains traces of chlorine compounds. Sabanejeff[2] also mentions that, on boiling copper acetylene with hydrochloric acid, an oily matter was formed which condensed in the wash bottles, and Berthelot considered this to be acetylene hydrochloride, $C_2H_2, 2HCl$, but came to this conclusion without apparently either making an analysis of the body or testing its boiling-point.

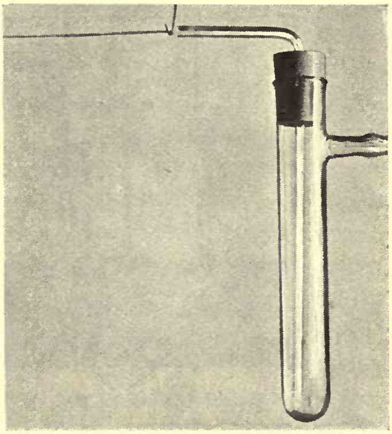


FIG. 8.

This oily substance distils completely at between 56° and 58° C., and is presumably ethylidene chloride, which Bunte has shown to have a boiling-point of 57·5°.

Many attempts were made by Polis to get pure acetylene by the action of hydrochloric acid on copper acetylene, but it was always found to contain

[1] *Lieb. Ann.*, 233, 182. [2] *Ibid.*, 178, 111.

the chlorine compound, which, calculated as ethylidene chloride, amounts to as much as 0·08 per cent.

The Polis tube for showing the presence of Acetylene in flames

By far the most elegant method of showing the presence of acetylene in the flames given by compounds containing carbon is that devised by Polis.[1] A test tube with side tubulure, Fig. 8, is fitted with a cork, through which passes a glass tube bent at right angles, into the end of which is fused a tube of platinum 0·5 mm. in diameter. The test tube is half filled with the ammoniacal cuprous chloride solution,

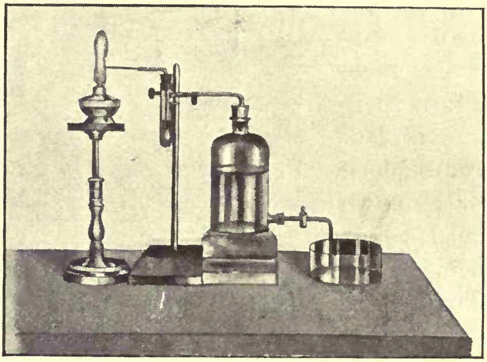


FIG. 9.

and the side tubulure attached to an aspirator bottle (Fig. 9). On now placing the tip of the platinum tube in the flame to be tested, and allowing the water to flow from the aspirator bottle, the gases from the interior of the flame are sucked through the test solution, and the presence of acetylene is at once made manifest by the formation of the red copper acetylene.

This form of apparatus is well adapted for projection on the screen.

[1] *Zeitsch., ver. d. Ing.*, 39, 1337.

C.—The Preparation of Acetylene by passing Organic Vapours and Gases through Heated Tubes.

The decompositions of the simpler forms of hydrocarbons at an elevated temperature have always been recognised as a question of the greatest importance, as upon them is dependent a true conception of many of the actions taking place in the manufacture of coal gas and other kindred processes of destructive distillation.

Importance of the action

It was Boettger[1] who, in 1859, first recognised that the destructive distillation of resin, resinous wood, coal, and other substances of the same kind, yielded a gaseous mixture which contained a gas capable of giving a red precipitate on passing through an ammoniacal solution of cuprous chloride; and the researches of Berthelot[2] showed that acetylene might be prepared by allowing the vapours of alcohol, ether, aldehyde, methylic alcohol, and also the hydrocarbons methane and styrolene, to pass through red-hot tubes, and since that time a considerable amount of work has been done upon that subject, as, although it is not a method which serves for the convenient preparation of acetylene on a large scale, it is of very great theoretical interest.

Formation of Acetylene during destructive distillation

Berthelot shows that Acetylene is formed by the action of heat on organic vapours

Ethylene has in most cases been chosen as the hydrocarbon which would lend itself most readily to researches upon this point, as, besides being one of the simplest, it is easily prepared, and is, moreover, found as one of the products in nearly all cases where organic compounds are subjected to distillation at high temperatures.

Work of the early observers

No sooner had the difference between ethylene and methane been recognised, than experiments were made by Deimann, Van Troostwyk, Lauwerenberg, and

[1] *Ann. Chem. Pharm.*, 109, 351. [2] *Compt. Rend.*, 54, 515.

Bondt,[1] to ascertain the action of heat upon the newly-formed compound, and the conclusions to which they came were, that on heating no contraction in volume was observed, but that the tubes in which the decomposition was effected became coated with a black deposit, and drops of an oily body were formed, the gas at the same time losing its property of forming an oily liquid with chlorine.

Action of high temperature on Ethylene

These experiments were afterwards repeated by Fourcroy, Hecht, and Vauquelin,[2] who showed that, when heated, ethylene yields hydrogen with deposition of carbon; whilst in 1805 William Henry [3] showed that ethylene was formed during the destructive distillation of organic bodies, and that on further heating the gas other changes were observed, and the gas eventually converted into hydrogen and carbon. The deposition of carbon was also noticed later by Quet,[4] who, on passing sparks through ethylene, found that carbon was deposited and formed a bridge between the poles used for the discharge, whilst Dalton showed, by the continuous action of the electric spark, that ethylene yielded double its own volume of hydrogen, carbon being deposited.

Decomposition of Ethylene to Carbon and Hydrogen

Marchand and Magnus show that Methane is formed on heating Ethylene

Marchand [5] came to the conclusion that at a red heat this gas splits up into methane and carbon, but at a white heat into carbon and nearly pure hydrogen; whilst Magnus, in 1847,[6] made the important observation that on leading ethylene through a red-hot tube a contraction in volume followed: the residual gas consisted of methane, hydrogen, and unchanged ethylene, whilst carbon was deposited and fluid and even solid hydrocarbons were obtained.

In 1860 H. Buff and A. W. Hofmann [7] published a

[1] *Ann. Chim. Phys.*, 1st series, 21, 48.
[2] Gilbert's *Annalen*, 2, 210.
[3] Nicholson's *Journal*, 1805.
[4] *Compt. Rend.*, 42, 903.
[5] *Journ. Prakt. Chem.*, 26, 478.
[6] *Pogg. Ann.*, 80, 470.
[7] *Lieb. Ann.*, 113, 119.

paper on the "Dissociation of Gaseous Compounds on Heating by Electricity."

Decomposition of the gas by a heated spiral

They found that when a platinum spiral was heated by the galvanic current in pure ethylene, there was at once a visible separation of carbon, which covered the sides of the tubes with a black deposit, whilst hardly any expansion took place in the volume of the gas, from which they assumed that the ethylene had split up into methane and carbon.

Decomposition of Ethylene by the electric spark

If the action on the gas, due to the incandescent platinum wire, was allowed to continue, then an increased amount of the gas underwent dissociation, and soon after the separation of carbon commenced they observed a rapid expansion, which in ten minutes reached a maximum. Similar phenomena were observed with the spark current. At first the spark had a pale reddish tint, which gradually turned to violet, immediate separation of carbon taking place, the spark being frequently stopped by scales of carbon, which formed a bridge between the poles. They found that, under these conditions, the volume of gas expanded very slightly at first, and afterwards more slowly still, and that after twenty to twenty-five minutes the point of maximum expansion was reached, so that 7 cc. of dry ethylene gave after decomposition 12·25 cc. They noted also that the residual hydrogen had an unpleasant smell, and burnt with a slightly luminous flame.

Berthelot shows that the decomposition of Ethylene yields Acetylene

Berthelot, in 1869,[1] claimed that ethylene would break up under the influence of heat into acetylene and hydrogen, as expressed by the equation—

$$C_2H_4 = C_2H_2 + H_2,$$

and showed that the acetylene then polymerised into benzene, styrene, and other liquid products of higher boiling-points. Naphthalene was also formed by the direct condensation of styrene and acetylene. He also

[1] *Ann. Chim. Phys.*, 4, 16, 144.

pointed out that during the heating of ethylene a large proportion of ethane was formed, and his final conclusion was, that the heating of ethylene resulted in the splitting up of two molecules of ethylene into acetylene and ethane, and that the formation of solid and liquid products was due to the subsequent condensation of the acetylene.

In 1886[1] Davy made a number of experiments in order to determine the lowest point of temperature at which the constitution of ethylene undergoes alteration, and the nature of the changes taking place at that temperature. In order to do this he devised an ingenious apparatus in which the ethylene could be heated for very long periods in a hard glass tube. From these experiments he concluded that when the action was continued over a long period, the gas underwent change at much lower temperatures than had been previously observed. The alteration in constitution commenced at about 350° C., at which temperature the change was one of condensation without the formation of members of any series of hydrocarbons having a percentage of hydrogen and carbon different from ethylene; whilst if ethylene was maintained at 400° for a sufficient length of time, it was entirely decomposed, marsh gas, ethane and liquid products being obtained.

Morton and Noyes

In the same year Morton and Noyes[2] made an elaborate investigation with the object of determining whether crotonylene, C_4H_6, which is present in small quantities in illuminating gas and other products of the distillation of organic matter, is formed as a primary product of decomposition by heat, or as a secondary product of the action of heat upon ethylene.

Coal gas was passed slowly through a hard glass tube, 15 mm. in diameter, which was maintained at a low red heat for a distance of 60 cm. The products

[1] *American Chem. Journ.*, 8, 153. [2] *Ibid.*, 8, 362.

issuing from this tube were first passed through a series of U tubes, surrounded by a freezing mixture; the products which were not condensed were passed through an ammoniacal solution of cuprous chloride, to absorb hydrocarbons of the acetylene series, whilst samples of the gases escaping absorption were finally collected over water. Carbon was deposited in the decomposition tube, and at the end of one month 15 cc. of liquid had been slowly condensed in the U tubes, and in this liquid they detected benzene, naphthalene, and some other aromatic hydrocarbons, present in quantities too small for determination. Faint traces only of precipitate were found in the ammoniacal cuprous chloride solution, whilst amongst the bodies absorbed by bromine they identified crotonylene tetra-bromide, and the gas collected over water proved to be a mixture of methane and ethane. The absence of acetylene from the products obtained led them to the view that these products were formed directly by the action of heat upon ethylene.

The liquid Hydro-carbons formed from Ethylene

From the work of the earlier observers the text books have accepted the equation

$$C_2H_4 = C_2 + 2H_2$$

as representing the decomposition which takes place at a very high temperature, whilst, on the evidence of the work done by Marchand and Buff and Hofmann, they represent the change taking place at a lower temperature by the equation

The actions generally considered as taking place when Ethylene is heated

$$C_2H_4 = C + CH_4.$$

These reactions, however, in no way explained the formation of the more complex liquid and solid bodies formed when ethylene is heated, and Lewes,[1] having worked upon the effect of heat upon ethylene, came

Lewes's conclusions as to the action of heat on Ethylene

[1] *Proc. Roy. Soc.*, 55, 90.

to the conclusion that the primary action might be represented by the equation

$$3C_2H_4 = 2C_2H_2 + 2CH_4.$$

The formations of complex hydro-carbons.

The nascent acetylene so formed polymerises with great rapidity, forming in the first place benzene, C_6H_6, and, at a slightly higher temperature, styrolene, C_8H_8; whilst a still further rise of temperature yields naphthalene,

$$5C_2H_2 = C_{10}H_8 + H_2,$$

and higher tar-like products, whilst at the same time the hydrogen combines to a small extent with acetylene, reforming ethylene. The methane also formed in the primary reaction splits up into acetylene and hydrogen,

$$2\ CH_4 = C_2H_2 + 3\ H_2;$$

and the various compounds present, by further polymerisation and interaction amongst themselves, give rise to the many compounds noticed by various observers.

The rapidity with which the freshly generated acetylene polymerises renders it impossible to obtain more than a slight percentage of the free acetylene in the gaseous mixture; and as the temperature reaches the decomposing point of the acetylene, which varies according to the amount of the dilution, polymerisation ceases, and the acetylene splits up directly into carbon and hydrogen, and, all the other products doing the same thing, the final reaction yields carbon and hydrogen only.

D.—The Preparation of Acetylene by the Chemical Decomposition of Organic Compounds.

Before the introduction of calcium carbide, methods for the preparation of acetylene based upon chemical interactions between the halogen compounds of

certain hydrocarbons and alkalies were used with considerable success.

Decomposition of Ethylene Chloride

It was De Wilde, in 1874,[1] who noticed that when the vapour of ethylene chloride was passed through a tube filled with lime, or, better, soda lime, heated to redness in a combustion furnace, the chlorine of the organic compound united with the metal to form chlorides of calcium and sodium, whilst water and acetylene were generated.

The gas produced by this method

The acetylene thus set free was absorbed by ammoniacal cuprous chloride in the usual way, and the copper acetylene used for the generation of the gas, although when yielded by this method it is, as a rule, so pure that in most cases it would be possible to use the gas direct from the decomposing-tube.

The decompositions taking place

The reactions taking place may be represented by the equations—

$$\underset{\text{Ethylene Chloride.}}{C_2H_4Cl_2} + \underset{\text{Lime.}}{CaO} = \underset{\text{Calcium Chloride.}}{CaCl_2} + \underset{\text{Water.}}{H_2O} + \underset{\text{Acetylene.}}{C_2H_2}$$

and

$$\underset{\text{Ethylene Chloride.}}{C_2H_4Cl_2} + \underset{\text{Sodium Hydrate.}}{2\,NaHO} = \underset{\text{Sodium Chloride.}}{2\,NaCl} + \underset{\text{Water.}}{2\,H_2O} + \underset{\text{Acetylene.}}{C_2H_2}.$$

Another method for the preparation of acetylene, still more widely employed, consists of decomposing ethylene bromide by boiling alcoholic potash.

Acetylene produced by decomposing Ethylene Bromide by Alcoholic Potash

The researches of Miasnikoff[2] in 1861 showed that the vapours of vinyl bromide, C_2H_3Br, could be decomposed by heated alcoholic potash with the liberation of acetylene; and in the same year Sawitch[3] showed that an identical action took place when ethylene bromide was used in place of vinyl bromide, whilst Sabanejeff,[4] in 1867, published a method of

[1] *Bull. Acad. Belg.*, 2, 19, No. 1.
[2] *Ann. Chem. Pharm.*, 118, 330. [3] *Ibid*, 119, 182.
[4] *Ibid*, 178, 111.

carrying out this reaction, which was an excellent way of preparing the gas, as it yielded nearly 75 per cent. of the calculated quantity of acetylene.

In the decomposition of ethylene bromide by boiling alcoholic potash the gas always contains a certain proportion of vinyl bromide, due to the reaction taking place in two stages.

The reactions leading to the liberation of Acetylene

1. Ethylene Bromide. Potassium Hydrate. Vinyl Bromide. Pot. Brom. Water.

$$C_2H_4Br_2 + KHO = C_2H_3Br + KBr + H_2O$$

2. Vinyl Bromide. Potassium Hydrate. Potassium Bromide. Water. Acetylene.

$$C_2H_3Br + KHO = KBr + H_2O + C_2H_2$$

Apparatus used

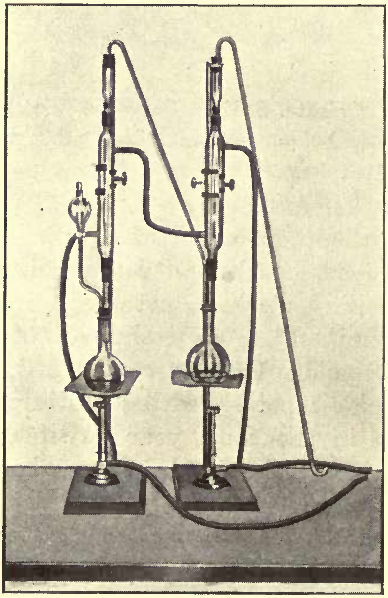


Fig. 10.

In order to remove this bromide the mixed gases are again passed through boiling alcoholic potash. The apparatus employed, Fig. 10, is made by taking a small wide-necked flask fitted with a cork carrying a dropping funnel and a reflux condenser; a delivery tube from the upper end of the condenser passes into a second similar flask also carrying a reflux condenser,

this tube reaching nearly to the bottom of the flask. A second delivery tube carries the gas to the pneumatic trough. Alcoholic potash is gently heated in both flasks, and ethylene bromide allowed to drop into the first. The gas which is produced carries with it the vapours of alcohol and ethylene bromide, some of which is condensed in the first reflux condenser and is returned to the flask. Such vinyl bromide as is carried forward is decomposed by being made to bubble through the alcoholic potash contained in the second flask, and the gas, which passes, after being deprived of alcohol, through the second condenser, may be collected at the pneumatic trough, and will be found to be nearly pure acetylene.

Necessary precautions

Even after its second passage, however, through the boiling alcoholic potash it is not totally free from the vinyl bromide. Zeisel,[1] in order to finally purify this gas, passed it over gently-heated soda lime, which removed the last of the bromide compounds. Great care has to be observed in doing this, as, if the temperature is allowed to get too high, some of the acetylene undergoes polymerisation, and condensation products make their appearance in the acetylene, and have to be got rid of by passing through two wash bottles, the first containing alcohol and the second water.

Final purification of the gas

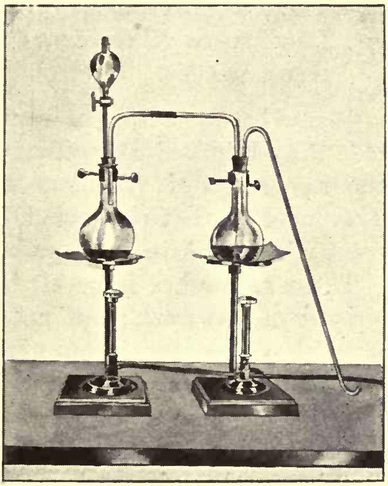


Fig. 11.

[1] *Ann. Chem. Pharm.*, 191, 368.

If only small quantities of acetylene are required to demonstrate that the gas is formed by the action of hot alcoholic potash on ethylene bromide, the reflux condensers may be omitted, and the simplified apparatus shown in Fig. 11 may be used.

Cazeneuve's method for the preparation of Acetylene

Another method of preparing the gas is due to Cazeneuve[1]. 500 grammes of zinc dust are placed in a flask with 20 grammes of bromoform, and a 2 per cent. solution of copper chloride is then added, the copper depositing upon the zinc, and forming a galvanic couple which acts upon the bromoform, with the formation of zinc bromide, and the liberation of acetylene.

Bromoform.		Zinc.		Zinc Bromide.		Acetylene.
$2CHBr_3$	+	$3Zn$	=	$3ZnBr_2$	+	C_2H_2

This reaction is a useful one, as it proceeds with considerable rapidity and gives a good yield of the gas.

E.—The Preparation of Acetylene by the Double Decomposition of certain Carbides in contact with Water.

Potassium Carbide

It was by the action of water upon potassium carbide that Edmund Davy first made acetylene, whilst the researches of Woehler, Maquenne, Moissan, and Travers show that the carbides of several other metals react with water in the same way.

Moissan's researches on the Carbides

These researches have all been noticed in the first chapter of this work; but no mention of the carbides would be complete without giving *in extenso* Moissan's *résumé* of his magnificent researches as published in the *Comptes Rendus* of the Académie des Sciences.[2]

The action of metals at high temperatures on Carbon

" At the high temperature of the electric furnace a certain number of metals, such as gold, bismuth, and tin, do not dissolve carbon. Liquid copper takes up

[1] *Compt. Rend.*, 113, 1054. [2] *Ibid.*, 122, 1462.

but a very small quantity, but sufficient to change its properties and strongly modify its malleability. At the temperature of ebullition silver dissolves a small quantity of carbon, which it afterwards gives up, on cooling, in the form of graphite. This melted silver alloy, obtained at a high temperature, presents a curious property—that of increasing its volume when passing from a liquid to a solid condition. The phenomenon is analogous to that taking place with iron alloy, as both pure iron and silver diminish in volume in passing from a liquid to a solid condition. On the contrary, this alloy of silver or iron, under the same circumstances, increases in volume.

Increase of volume when alloys of Carbon with Iron or Silver solidify

The metals of platinum at their boiling-point dissolve carbon readily, and give it up again in the form of graphite on solidification. This graphite is abundant. A large number of metals, on the contrary, at the temperature of the electric furnace produce definite and crystalline compounds. We have already noted that Berthelot prepared carbides of potassium and sodium. By heating a mixture of lithium oxide, or carbonate of lithium, and carbon in his electric furnace, Moissan was able to obtain very readily transparent crystals of carbide of lithium which evolved 570 litres of pure acetylene per kilogram of the carbide. In the same way, by heating a mixture of oxides and carbon, he obtained in notable quantities crystalline carbides of calcium, barium, and strontium.

The formation of Crystalline Carbides

Carbides of Barium, Strontium, and Calcium

All these carbides are decomposed upon contact with cold water, giving off acetylene. The reaction is complete and the gas obtained pure. The three alkaline earth carbides correspond to the formula RC_2, and the carbide of lithium to the formula Li_2C_2. Another type of crystallized carbide, in transparent hexagonal plates one centimetre in diameter, is furnished by aluminium. This metal, strongly heated

Decomposition of Alkaline Earth Carbides by water

Carbide of Aluminium

in the electric furnace in the presence of carbon, produces yellow flakes which one can isolate by careful treatment with a dilute solution of hydrochloric acid cooled to the temperature of melting ice. This metallic carbide is decomposed by water at the ordinary temperature, producing alumina and pure methane gas. It corresponds to the formula Al_4C_3.

Carbide of Glucinium

Lebeau obtained, under the same conditions, the carbide of glucinium, which, according to his experiment, also produced methane upon contact with cold water. The cerite metals gave crystalline carbides, of which the formula resembles that of the alkaline earth carbides, RC_2. Moissan made a special investigation of the decomposition by water of the carbide of cerium CeC_2, lanthanum LaC_2, yttrium YtC_2, and thorium ThC_2. All these substances are decomposed by water, furnishing a gaseous mixture rich in acetylene and containing methane. The proportion of acetylene diminishes, and of methane increases with carbide of thorium. At ordinary pressures and high temperatures iron never gives a definite or crystalline compound. We have known for a long time, thanks to the researches of Troost and Hautefeuille, that manganese produces a carbide, Mn_3C. This carbide can be produced with the greatest ease in an electric furnace, and in contact with cold water it decomposes, giving off equal volumes of methane and hydrogen.

Carbides of Cerium, Lanthanum, Yttrium and Thorium

Carbide of Manganese

Carbide of Uranium

Carbide of uranium, Ur_2C_3, which Moissan obtained by the same process, gave a more complex reaction. This carbide, well crystallized and transparent, when in very thin plates, decomposed upon contact with water and gave a gaseous mixture, which contained a large quantity of methane, hydrogen, and ethylene. The most interesting fact presented by this carbide is that it not only gives off carburetted acids, but also an abundance of liquid

Liquid and solid products

and solid carbides, constituting two-thirds of its carbon content. The carbides of cerium and lanthanum, by their decomposition by water, furnish also liquid and solid carbides, but in less quantities.

All the carbides decomposable by water at ordinary temperatures, with the production of carburetted hydrogens, constitute the first class of compounds in the metallic carbide family. The second class would consist of carbides not decomposable by water at ordinary temperatures, such as a carbide of molybdenum Mo_2C, tungsten Tg_2C, and chromium Cr_4C and Cr_3C_2. The latter compounds are crystallized, not transparent, and have a metallic lustre. They possess great hardness, and melt only at elevated temperatures. Moissan has prepared all of them in his electric furnace.

Carbides not decomposable by water at ordinary temperatures

The metalloids, in contact with carbon at the electric furnace temperatures, produce definite and crystalline compounds, as, for example, the carbide of silicon, SiC, discovered by Acheson. This product is prepared on an industrial scale under the name of carborundum. The carbide of titanium, TiC, has a hardness so great as to scratch an impure diamond; the carbide of zirconium, ZrC, and the carbide of vanadium, VaC, may also be mentioned. A general fact may be deduced from the numerous experiments made by Moissan with his electric furnace. The compounds produced at high temperatures have always a very simple formula, and in most cases exist in but one combination. The reaction which appears to be the most curious is the easy production of gaseous liquid or solid hydrocarbons by the action of cold water upon certain metallic carbides. It would seem that these investigations might be of some geological interest.

Carborundum

Simple constitution of Metallic Carbides

The giving off of methane, more or less pure, which one encounters in certain formations, and

which has been taking place for centuries, might have its origin in the action of water upon carbide of aluminium. A similar action will explain the formation of liquid hydrocarbons. We know that the theories relating to the formation of petroleum are as follows: first, production through the decomposition of animal or vegetable organic matter; second, the formation of petroleums by purely chemical reactions, a theory first brought out by Berthelot, and which was the subject of a publication by Mendeleef; third, the formation of petroleum through volcanic phenomena, a hypothesis advanced by Humboldt in 1804.

The decomposition of Metallic Carbides in nature may explain the formation of Natural Gas and Petroleum

Starting with 4 kilograms of carbide of uranium, Moissan obtained in a single experiment more than 100 grams of liquid carbides. The mixture thus obtained is formed of ethylene carbides, a small quantity of acetylene carbides and saturated carbides. These carbides are formed in the presence of a large proportion of methane and hydrogen at ordinary temperature and pressure, a fact which caused Moissan to think that when the decomposition took place at high temperature there would be produced saturated carbides analogous to petroleum. Berthelot has, as a matter of fact, demonstrated that the direct fixing of hydrogen upon non-saturated carbides could be brought about by the action of heat alone.

Moissan's experiments

The existence of these new metallic carbides, decomposable by water, may in the future modify the theories which have been previously given to explain the formation of petroleums. One should guard against hasty generalizations, for, in point of fact, petroleums exist of different origin. At Autun, for example, the bituminous schists appear to have been produced by the decomposition of organic matter. On the contrary, in Limagne the asphalt impregnates the fissures of a limestone very poor in fossils. This

Petroleums and their occurrence

asphalt has a direct relation with the basaltic tuffs produced by volcanic action. A recent boring made at Riom brought some litres of petroleum from a depth of about 4,000 feet. The formation of the liquid carbide in this stratum could be attributed to the action of water. Moissan has shown in his note upon carbide of calcium the conditions under which this compound can be burned, giving off carbonic acid. As he has said in this note, it is probable that in the first geological periods of the earth nearly all of the carbon existed in the form of metallic carbides. When water enters into the reaction, the metallic carbides produce carbides of hydrogen, and the latter, by oxidation, carbonic acid. An example of this reaction can be found near Saint Nectaire, where the granites which constitute the border of the territory basin give off continuously large quantities of carbonic acid gas. Moissan thinks also that certain volcanic phenomena could be attributed to the action of water upon these easily decomposed carbides. All geologists know that the last manifestation of a volcanic centre consists in the emanation of a great variety of carbides, such as asphalt or petroleum, and finally, by reason of oxidation, carbonic acid. A movement of the strata of the earth brings the water in contact with the metallic carbides, and causes a violent evolution of gas. At the same time the temperature rises, the gases polymerise, and a series of complex products result, such as the hydrocarbons At certain places a volcanic fissure serves as an escape valve or chimney. We know that the nature of the gas collected in the fumeroles varies according to whether the volcanic phenomena take place in the ocean or in atmospheric air. At Santorin, for example, Fouqué has collected free hydrogen in the cavities of immersed volcanoes, while he has found only vapour of water in the superficial craters. The existence of these metallic

Natural production of Carbides

Possible action of Carbides in nature

carbides, so easy to prepare at high temperatures, and which probably would be met with in the interior of the earth, allows the explanation of certain volcanic eruptions owing to the formation of hydrocarbon gases, liquids or solids."

The production of Acetylene from Calcium Carbide

With calcium carbide, easily obtainable at a cheap rate, none of the older processes for making acetylene will be much employed except for lecture demonstration, as the acetylene obtained direct from a good sample of calcium carbide is in many cases purer than

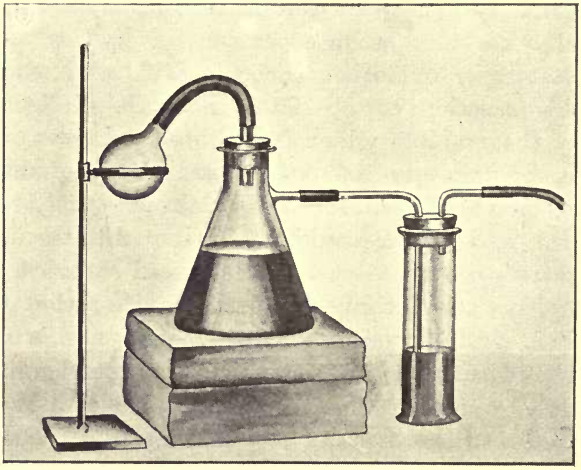


Fig. 12.

when the gas is produced by the decomposition of the copper acetylene compound by hydrochloric acid, this always containing, as previously pointed out, traces of chlorine compounds.

Apparatus used

The best method of preparing pure acetylene is to take a conical filtering flask, Fig. 12, with side tubulure, and to fit a wide tube, open at both ends, into the cork closing the mouth of the flask, the tube projecting into the flask to slightly below the level of the side tubulure; over the top of the tube is attached

a piece of wide indiarubber tubing, the other end being slipped over the mouth of a thick glass flask. The conical flask is now filled with a 25 per cent. solution of sugar, and the glass flask filled with pieces of good crystalline carbide, broken to about the size of peas; and when this is attached to the indiarubber tube, the weight of the carbide causes the flask to hang down. On raising it the carbide can be thrown a few pieces at a time into the water, and a steady evolution of the gas ensues. The gas is led from the

Method of evolving the gas

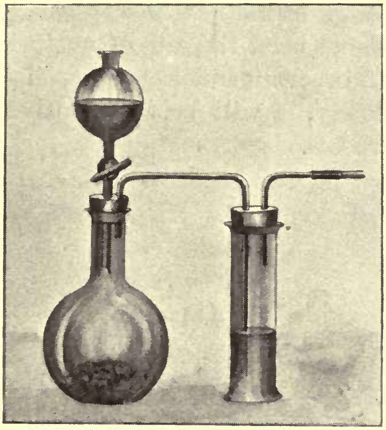


FIG. 13.

tubulure through a wash bottle in which is a 3 per cent. solution of sodium hypochlorite, and then through a tower, containing moistened sodium hydrate.

Removal of the impurities

The acetylene generated from the ordinary calcium carbide contains small traces of sulphuretted and phosphuretted hydrogen and ammonia; but when the evolution is carried on slowly in the way indicated, the sugar solution absorbs the ammonia, whilst the sodium hypochlorite removes the traces of phosphuretted and sulphuretted hydrogen. The gas generated in this way is purer than when made by

acting on the copper acetylene compound with hydrochloric acid.

Preparation from Carbide where absolute purity not essential

If the purity of the gas is not of great importance, the acetylene can be conveniently prepared by putting a layer of sand at the bottom of a 16-ounce flask, Fig. 13, and placing on the sand calcuim carbide in pieces the size of hazel nuts.

The flask is fitted with a cork carrying a dripping funnel and delivery tube, and the water is allowed to fall on the carbide a few drops at a time, the gas being led away through the washing cylinder and tower. When prepared in this way, the purity of the gas largely depends on the rate of evolution; as with carbide of fair commercial purity, if the gas be generated slowly, it will be sufficiently pure for all ordinary purposes.

CHAPTER III

ACETYLENE AND ITS PROPERTIES

EDMUND DAVY, in 1836, named the newly-discovered gas bicarburet of hydrogen, to mark the fact that he supposed it to be "composed of two proportions of carbon and one of hydrogen"; whilst later the name "klumene" was bestowed upon it, because it had been derived from a kalium[1] compound—potassium carbide.

Nomenclature

Klumene

It was Berthelot[2] who christened it "acetylene," from the fact that it bears the same relation to the radical acetyle, C_2H_3, that ethylene does to the radical ethyl, C_2H_5, and it is by this name that it is universally known, although attempts have been made to bring it under the more uniform system of vowel nomenclature proposed by Laurent and adopted by Hofmann, in which the different classes of hydrocarbons are distinguished by definite terminations, the C_nH_{2n+2} series having the termination "-ane," the C_nH_{2n} series "-ene," and the C_nH_{2n-2} series, of which acetylene is the simplest member, the termination "-ine." Hence the hydrocarbons containing two atoms of carbon would be—

Acetylene

Ethine

C_2H_6, ethane; C_2H_4, ethene; C_2H_2, ethine.

The ratio of carbon atoms to hydrogen, supposed to exist in the molecule of acetylene, reflects the various phases through which the atomic theory was passing in the early half of the century; and whilst

Ratio of Carbon to Hydrogen in Acetylene

[1] *Gmelin*, viii. 150.

[2] *Compt. Rend.*, 50, 805.

Davy expressed its composition as $C_2 + H$,[1] it was later doubled, and became C_4H_2;[2] whilst, when the atomic weight of carbon was recognised as 12 instead of 6, acetylene assumed the formula C_2H_2. During the period that these alterations were taking place in its nomenclature and symbolical representation, no variation of opinion existed as to its actual composition.

The formula for Acetylene

Davy found that it required two and a half volumes of oxygen to complete the combustion of one volume of acetylene, and that two volumes of carbon dioxide and one of water were produced. Berthelot[3] stated as the result of eudiometric analysis that the composition of acetylene was—

Determinations of composition

Carbon	92·3
Hydrogen	7·7
	100·0

And finally Moissan,[4] analyzing the gas developed by the action of water on calcium carbide, gives as his analytical data :—

Moissan's analysis of Acetylene from Calcium Carbide

Gas taken	1·28
Oxygen	15·15
Total gas	16·43
After explosion	14·50
After absorption with potash	11·98
Contraction	1·93
Carbon dioxide	2·52

whilst the formula C_2H_2 would require theoretically a contraction of 1·95 and 2·56 as the volume of carbon dioxide; hence the acetylene obtained from the carbide was practically pure.

These analytical results show that the ratio of carbon to hydrogen in acetylene is as 12 to 1, and the density of the gas at once shows that the molecule must be represented by the formula C_2H_2. It has a molecular weight of 26, and density 13.

Molecular weight and density of Acetylene

[1] *Brit. Assoc. Report*, 1836, 62. [2] *Gmelin*, viii. 150.
[3] *Compt. Rend.*, 50, 805. [4] *Le Four Electrique*, p. 297.

Specific gravity and weight

The specific gravity of the gas, as found by Berthelot,[1] was 0·92, whilst the determinations by Moissan[2] gave 0·907 and 0·912 respectively, the theoretical figure being 0·8985, and one litre weighs 1·165 grams at 0° C and 760 mm. pressure.

Heat of formation

In 1881 Thomsen[3] determined the heat of formation at constant volume and constant pressure, and found it to be −47,700 calories, so that acetylene is a highly endothermic compound; and on its decomposition the heat absorbed during its formation is again liberated.

Acetylene an endothermic compound

The specific heat was determined by Maneuvrier and Fournier,[4] who, as a mean of forty-two tests, find it to be 1·26.

Heat of combustion of Acetylene

The heat of combustion of acetylene has been determined by Berthelot and by Thomsen.

Berthelot

Berthelot[5] first made the determination by oxidation with potassium permanganate, and obtained 321,000 calories; whilst later,[6] by burning the gas in oxygen, he found 317,000 calories.

Afterwards, when working on explosives, he determined[7] the heat evolved by the detonation of the gas at constant volume, and obtained 314,900 calories, whilst at constant pressure the result was 315,700 calories.

Thomsen

Thomsen,[8] as the mean of several determinations made by direct combustion, found 310,000 calories.

Heats of formation of bodies from Acetylene

Berthelot[9] has also given the heat of transformation of acetylene into other compounds as follows:—

Carbon Dioxide and water

1. The oxidation of acetylene into carbon dioxide and water—

$C_2H_2 + 5O = 2\ CO_2 + H_2O$ (liquid) + 321,000 calories.

[1] *Compt. Rend.*, 50, 805.
[2] *La Four Electrique*, 297.
[3] *Thermoch. Unters.*, 4, 74.
[4] *Compt. Rend.*, 124, 183.
[5] *Ann. Chim. Phys.* (5), 9, 165.
[6] *Ibid.* (5), 13, 14.
[7] *Ibid.* (5), 23, 180.
[8] *Thermoch. Unters.*, 4, 74.
[9] *Compt. Rend.*, 82, 24–28.

Oxalic Acid

2. The formation of oxalic acid (solid) from acetylene—

$$C_2H_2 + 2O_2 = C_2H_2O_4 + 260{,}800 \text{ calories.}$$

Acetic Acid

3. The formation of crystalline acetic acid—

$$C_2H_2 + O + H_2O = C_2H_4O_2 + 113{,}500 \text{ calories.}$$

Formic Acid

4. The formation of crystalline formic acid—

$$C_2H_2 + 2O_2 = CH_2O_2 + CO_2 + 253{,}500 \text{ calories.}$$

Ethylene

5. The formation of ethylene—

$$C_2H_2 + H_2 = C_2H_4 + 56{,}000 \text{ calories.}$$

Prussic Acid

6. The formation of prussic acid (gaseous)—

$$C_2H_2 + N_2 = 2HCN + 36{,}000 \text{ calories.}$$

Benzene

7. The formation of liquid benzene—

$$3(C_2H_2) = C_6H_6 + 190{,}000 \text{ calories (nearly);}$$

Specific heat of Acetylene Hydrate

whilst Villard[1] found the heat of formation of the hydrate $C_2H_26H_2O$ to be + 1,540 calories.

Occurrence

Acetylene occurs in minute traces in coal gas, and all other gases produced by the destructive distillation of organic matter containing hydrogen and carbon, whilst it is invariably found in the interior of all hydrocarbon flames.

Smell of Acetylene

It is a clear colourless gas, having a sweet ethereal odour, the unpleasant smell noticeable in the gas as ordinarily prepared being due to impurities, and disappearing as soon as the gas is properly purified.[2]

Solubility of the gas in water

Davy,[3] in his original memoir, states that recently-boiled distilled water absorbs about its own volume of the gas; and Lewes[4] finds that at 15° C., and 760 mm. ten volumes of water dissolve eleven of the gas, water already saturated with coal gas not taking up acetylene so readily; whilst in a saturated salt solution it is practically insoluble, 100 volumes of brine only absorbing five of the gas.

Solubility under pressure

The amount of gas dissolved increases with the

[1] *Compt. Rend.*, 120, 1262.

[2] See under Purification, part II.

[3] *Brit. Assoc. Report*, 1836, 62. [4] *Journn. Soc. Arts*, 43, 159.

pressure; and Villard[1] found that one volume of boiled water at 0° C. dissolved 1·6 volumes of acetylene at 4·65 atmospheres pressure.

Solubility of Acetylene in various liquids

Berthelot[2] tried the solubility of acetylene in various liquids, and gave as the result of his experiments:—

1 vol. of water	at 18° C. and 760 mm.	dissolves	1	vol. of	acetylene.
,, carbon disulphide	,,	,,	1	,,	,,
,, pentane	,,	,,	1	,,	,,
,, turpentine	,,	,,	2	,,	,,
,, carbon tetrachloride	,,	,,	2	,,	,,
,, amyl alcohol	,,	,,	3·5	,,	,,
,, styrolene	,,	,,	3·5	,,	,,
,, chloroform	,,	,,	4	,,	,,
,, benzol	,,	,,	4	,,	,,
,, acetic acid	,,	,,	6	,,	,,
,, alcohol	,,	,,	6	,,	,,

Solubility in Acetone

According to Fuchs and Schiff,[3] 100 volumes of olive oil only absorb 48 volumes of acetylene.

Claude and Hess[4] noticed in 1897 that 1 volume of acetone at 15°, and under ordinary pressure, dissolves 25 volumes of acetylene, and under 12 atmospheres 300 volumes. Thus the solubility increases nearly in proportion to the pressure. The solubility in acetone is diminished by half on passing from 15° to 50°; and therefore the pressure in a reservoir doubles for a rise of about 30°. With liquid acetylene a pressure of 24 atmospheres increases to 70 for a rise of 18°. Dissolved acetylene may therefore be stored safely in weaker and lighter vessels than liquid acetylene; and since its coefficient of dilatation is very much lower, the vessels may be more nearly filled. A platinum wire, maintained at bright redness by electric current, was held for an indefinite period with impunity in a solution of acetylene in acetone made under a pressure of 3 atmospheres.

Advantages of the solution in Acetone over liquid Acetylene

The safety of solutions of acetylene in acetone is an

[1] *Compt. Rend.*, 120, 1262.
[2] *Ann. Chim. Phys.* (4), 9, 425.
[3] *Chem. Zeit.*, 1897, 895.
[4] *Compt. Rend.*, 124, 626.

important question, as were the solution free from the dangers inseparable from liquid acetylene,[1] it would be possible under pressure to store more acetylene in solution in acetone in a given space, than would be possible with acetylene liquefied *per se*.

Berthelot and Vielle's research on the safety of Acetone solutions

This point was made the subject of an exhaustive research by Berthelot and Vielle,[2] who studied the properties of solutions of acetylene in acetone under three heads :—

1. Pressure of Dissolved Acetylene

Pressure exerted by dissolved Acetylene

Details are given of the pressures over a range of about 60° C. of solutions containing respectively 69 gr. of acetylene and 301 grs. of acetone, 118 grs. of acetylene and 315 grs. of acetone, and 203 grs. of acetylene and 315 grs. of acetone. The most important results are that the observed pressures follow the same general law as the pressures of the saturated vapour of a homogeneous liquid, and are attributable almost entirely to the acetylene; the pressure attributable to the acetone forms only a small fraction—a few hundredths—of the total pressure.

2. Liability of Dissolved Acetylene to Detonate

Liability of dissolved Acetylene to detonate

The explosion of 1·5 gr. of fulminate of mercury in a metallic bottle of 700 cc. capacity, containing 320 grs. of acetone and 132 grs. of acetylene, caused a dull noise with escape of gas. The bottle was cracked, but there was no explosion nor inflammation. In an identical experiment made by the authors with liquefied acetylene the bottle was smashed to small fragments.

3. Liability of Dissolved Acetylene, and of the Vapour, to Inflame

Inflammability of dissolved Acetylene

A 50 cc. steel tube, provided with crusher gauges, was charged with 14 cc. of acetone in a first set of experiments, and 8·2 cc. in a second set. The acetone

[1] See page 87. [2] *Compt. Rend.*, 129, 988.

was saturated with acetylene at the ordinary temperature, and at pressures varying from 10 to 20 kilos. per square cm.; when the initial pressure did not exceed 10 kilos., and the ignition was produced by an incandescent platinum wire in the gas, the observed pressures did not differ from those corresponding to the combustion of pure acetylene under the same pressure. From this it may be concluded that the dissolved acetylene is not decomposed, and that it takes no part in the combustion. The maximum pressures observed are only one-tenth of those which would correspond to the explosive decomposition of the whole of the contained acetylene, gaseous and dissolved. But when the initial pressure exceeds 10 kilos., the effect produced becomes analogous to the explosion of pure liquid acetylene. Not only is the acetylene decomposed, but the acetone which holds it in solution is also destroyed simultaneously. The explosive decomposition produces a compact mass of carbon, which takes the form of the tube. The gases formed consist of hydrogen and carbon monoxide mixed with carbonic acid. The experiments have been repeated with a larger receiver (13·5 litres) of the kind commercially used. It is found that the bottle ordinarily used, tested to 250 atmospheres, can support without rupture the pressure resulting from an accidental inflammation of the gaseous atmosphere contained in the bottles, the acetone having been saturated with acetylene at pressures of 6 to 8 kilos., and temperatures of 10° to 15° C. The pressure developed does not exceed 155 kilos. But these bottles are no longer safe if the initial pressure exceed 10 kilos, or if they are exposed to temperatures exceeding 35° C. With an initial pressure of 20 kilos., when the inflammation is produced in a gaseous atmosphere, it can develop a pressure of 568 kilos.; and when it is produced in the liquid itself, the pressure rises to 5,100 kilos. No commercial receiver is safe under such conditions.

Pressures observed

Strength of bottle needed to resist pressures found

Limits of safety

Conclusions arrived at by Berthelot and Vielle

Finally, acetylene is less dangerous when dissolved in acetone, for it cannot be exploded by internal inflammation when the pressure is below 10 kilos. and the temperature is below 15° C. Acetylene *per se* can be exploded by internal ignition when a receiver of a litre capacity contains 2·5 grs. or more. Under the conditions stated the same receiver could contain without risk nearly fifty times as much acetylene—100 to 120 grs.—dissolved in acetone.

Explosive decomposition of the solution

Further,[1] they find that when acetylene is heated in contact with its solution in acetone, in a closed receiver, under certain conditions the dissolved acetylene suffers no decomposition, whilst under other conditions it suffers explosive decomposition. In the latter case the solvent, acetone, is decomposed, and, in the main decomposed into its elements, the oxygen appearing in the form of carbon monoxide and dioxide and water—

$$4C_3H_6O = \begin{cases} 5C + 12H + CO_2 \\ 5C + 10H + CO + H_2O. \end{cases}$$

Cause of the decomposition of the solvent

This total decomposition of the solvent is produced by the explosive shock resulting from the destruction of the acetylene at constant volume. It is exceptionally interesting as an example of the sudden and total destruction of a substance which is formed, as acetone is, with evolution of heat. The determining factor in the conditions is the pressure. The authors proceed to explain from thermochemical considerations why acetylene dissolved in acetone is stable up to a certain pressure—about 10 kilos. per square cm. The decomposition of 20 grs. of gaseous acetylene into its elements evolves +51·4 calories; allowing for the heat of solution of dissolved acetylene, this would be reduced to +46·3 calories. The heat of vaporization of a molecule of acetone is 7·5 calories, so that the decomposition of a molecule of acetylene would suffice to vaporize

Heat generated

[1] *Compt. Rend.*, 129, 996.

6 molecules, or thirteen times its weight of acetone. Such would be the effect produced in a solution containing 77 grs. of acetylene per kilo. of acetone. To this must be added the heat required to heat to the same temperature the carbon and hydrogen produced by the decomposition of the acetylene. Clearly the high temperature required for the destruction of the acetylene cannot be attained under these conditions; a much larger percentage of the endothermic compound is required. At a pressure of 10 kilos. per square cm., 1 kilo. of acetone dissolves 350 grs. of acetylene; the latter by its own decomposition would evolve 623·3 calories. This at constant volume would raise the mixture of acetone—supposed to be unaltered,—carbon, and hydrogen to 730° at most. Now this temperature is not high enough to decompose acetylene into its elements. A similar calculation for acetone, saturated with acetylene, under a pressure of 20 kilos., and containing 700 grs. of acetylene per kilo. of acetone, gives a temperature of 1,300°, which is above the actual temperature of decomposition of acetylene. These calculations are only approximate, and reference must be made to the original for further developments; *e.g.*, the heat absorbed in the decomposition of the acetone into carbon, hydrogen, and carbonic acid would reduce the above temperature to 1,160° C. But this same decomposition would determine an increase of volume from 1 to $3\frac{1}{2}$, or at constant volume a corresponding increase of pressure. Taking both into account, the decomposition of acetone would result in the doubling of the final pressure, as compared with that due to the decomposition of the acetylene alone. Under high initial pressures, therefore, the acetone might become a source of danger rather than of safety.

Thermal reasons for the safety of a solution of Acetylene in Acetone at a pressure of less than 10 kilos. per square centimetre

Acetylene was first liquefied by Cailletet[1] in 1877; but from the figures he experimentally arrived at the

Liquefaction of Acetylene

[1] *Compt. Rend.*, 85, 851.

Ansdell's research on the liquefaction of Acetylene

gas used must have been impure; and in 1879 the work was repeated by Ansdell[1] in the laboratory of the Royal Institution, and as his research still remains the most important and reliable work on the subject, it is well to reproduce it *in extenso.*

He uses for this work one of Cailletet's pumps, but points out that in doing so he employed a carefully calibrated air manometer instead of the ordinary metallic gauge attached to the pump, which was far from being correct.

Cailletet pump

"The pump itself is too well known to need description; suffice it to say that two of the iron bottles or reservoirs were used, connected with the pump by a piece of fine-bore copper tubing, so as to equalize the pressure, one containing an air manometer registering the pressures from ten atmospheres upwards, and the other the tube filled with acetylene. The two bottles were then placed side by side, and the height of the column of mercury in either read off by means of a cathetometer.

Arrangement of the apparatus

"The formulæ used for calibrating the tubes, and also for calculating the volume of the liquefied gas, and the pressure by the air manometer, were those given by Dr. Andrews in his researches on carbonic acid (*Phil. Trans.*, 1869 and 1876). The method of preparing the acetylene gas was by the action of alcoholic potash on bibromethylene, the disengaged gas being collected in the form of the red acetylide of copper by passing it into a strong solution of the subchloride of copper in ammonia. This red compound, after being thoroughly washed and boiled with distilled water, was transferred to a flask with dilute hydrochloric acid, the gas driven off by means of a gentle heat, and conducted through a strong solution of caustic soda, to free it from traces of hydrochloric acid, and finally through two small U

Preparation of the Acetylene used

[1] *Proc. Roy. Soc.*, 29, 209.

tubes with fused chloride of calcium. The perfectly pure and dry acetylene was now passed through the tube to be used for its liquefaction in a slow stream for several hours, and the latter carefully sealed off when all the air had been expelled.

"The sealing off requires great care, as unless rapidly done, and the pressure removed from the inside by cooling the tube, immediately the point is closed the acetylene becomes charred and blown out, a small portion of it being consequently decomposed, and thus interfering materially with the accuracy of the results.

"The tube for the tension determinations was of the usual shape used in the Cailletet pump, the internal diameter of the capillary part being about 2·5 mm. This was found to be more convenient than a narrower tube, as a larger reservoir could be used, and consequently a larger quantity of liquid obtained.

"The pressure at the different temperatures was always observed when a very slight layer of liquid was formed on the surface of the mercury; as the gas not being entirely free from air, the pressure was slightly increased on filling completely the upper part of the tube.

"The following are the tensions obtained compared with those of Cailletet:—

The tension of liquid Acetylene as observed by Ansdell and Cailletet

		Cailletet.	
Temperature.	Pressure.	Temperature.	Pressure.
−23° C.	11·01 atm.		
−10	17·06		
0	21·53	+1·0° C.	48 atm.
+ 5·25	25·48	2·5	50
13·5	32·77	10·0	63
20·15	39·76	18·0	83
27·55	48·99	25·0	94
31·6	56·2	31·0	103
36	65·36		
36·5	65·89		
36·9	67·96		

"The temperatures above zero were kept constant to within one-twentieth of a degree by allowing a constant stream of water to flow over the tube from a reservoir holding about 45 litres, in which it had been previously thoroughly mixed. The temperature of $-10°$ was obtained by cooling down alcohol with ice and salt, and that at $-23°$ by surrounding the tube with a narrow glass cylinder containing liquid chloride of methyl, which boils constantly at this temperature, this cylinder being again enclosed in a wider one containing a little phosphoric anhydride to prevent moisture from condensing on the sides.

The cooling arrangements employed

Comparison of the tension of liquid Acetylene and Benzene vapour

"It was thought interesting to compare the tensions of liquid acetylene with those of the saturated vapour of benzene, being polymeric bodies, although having totally different principles. For this purpose curves were plotted for the two substances, that for the benzene being taken from Regnault's results (*Mém. Acad. Sci.*, Paris, vol. xxvi. p. 420). They do not, however, run parallel to each other, the benzene having a slower rate of increase at low temperatures, but a quicker rate than the acetylene as the temperature rises.

"The curves, however, have no appearance of actually crossing at higher temperatures.

The critical point of Acetylene

"The critical point of acetylene, or that temperature at which no appearance of liquefaction takes place, however great a pressure is exerted on the gas, was found, after many careful experiments, to be 37·05° C."

Villard's experiments on the liquefaction of Acetylene

Villard,[1] in 1895, criticised Ansdell's method of preparing the acetylene, and points out that when the gas is liberated from the copper acetylene compound, the products of its combustion always contain hydrochloric acid, and that therefore the acetylene may have contained chlorine compounds.[2]

[1] *Compt. Rend.*, 120, 1262. [2] See page 43.

Villard made acetylene by acting on calcium carbide with water, and, after purifying it as much as possible, led it into water under pressure, when crystals of a hydrate, C_2H_2, $6A_2O$, are formed, and, being heavier than water, sink to the bottom.

Preparation of pure Acetylene from Crystalline Hydrate

These crystals dissociate at ordinary temperatures when the pressure is removed, and the gas, when dried, is pure acetylene. His determinations with the purified gas gave the following results :

Villard's determinations

Temperature.	Pressure.	Temperature.	Pressure.
−90° C.	0·69 atm. solid	−23·8° C.	13·2 atm.
−85	1·0	0·0	26·5
−81	1·25 melting point	+ 5·8	30·3
−70	2·22	11·5	34·8
−60	3·55	15·0	37·9
−50	5·30	20·0	42·8
−40	7·7	37	68 critical point

In 1895 also Willson and Suckert,[1] in a paper read before the Franklin Institute, gave the following figures for commercial acetylene prepared by calcic carbide :

Willson and Suckert

Temperature.	Pressure.
−82·2° C.	1·0 atm.
−33·6	9·0
−23·0	11·1
−10·0	17·06
0·0	21·53
+ 5·3	25·48
13·5	32·77
19·5	39·76

These figures show a remarkable coincidence with those given by Ansdell between the temperatures of −23° and +13·5°.

In 1896 Raoul Pictet[2] made the astounding statement that the figures obtained by previous observers were too high, and that when acetylene made by the action of water on calcic carbide was purified

Pictet on the liquefaction of Acetylene

[1] *Journ. Franklin Instit.*, 139, 327.

[2] *L'Acétylene Génève*, 1896, 66.

by his physico-chemical process of passing it through a solution of calcic chloride cooled to $-40°$ C, and then through sulphuric acid at a low temperature, and finally through lead salts, the following table would represent the tension of the acetylene at the various temperatures indicated :

Temperature.	Pressure.
1·6° C.	21·5 atm.
9·5	27
14·1	29
19·5	33·5
27·6	38·5
36·5	48
47	68

The most extraordinary figure in this table being the last, which credits the acetylene at 10° above its critical temperature with no greater pressure than at its critical point, as determined by such careful observers as Ansdell and Villard.

Liquid acetylene is colourless and very transparent, and its presence in a tube can only be seen by noticing the upper meniscus.

The density and compressibility of the liquid were fully studied by Ansdell :[1]

Ansdell's experiments on the density and compressibility of liquid Acetylene

"For determining the density and compressibility of the liquid at different temperatures, a tube was used having a capillary bore of about 8 mm. in diameter, the whole of the tube having a capacity of 36·3708 cub. cm. This gave a column of liquid about 15 cm. long, when the upper part of the tube was entirely full at 15° C.

"The density at any particular temperature was taken by forcing the liquid up the capillary tube at that temperature until the upper part was completely filled ; the length of the column of liquid was then read off, its volume calculated, and this observed

[1] *Proc. Roy. Soc.*, 29, 212.

volume divided into the calculated weight of the gas at zero. They are as follows:

Temperature.	Density.	Temperature.	Density.
−7° C.	0·460	16·4	0·420
−3	0·456	20·6	0·413
0	0·451	26·25	0·404
4·4	0·441	30·0	0·397
9·0	0·432	34·0	0·381
		35·8	0·364

The density of liquid Acetylene

"It has therefore about half the density of liquid carbonic acid; and if we take the actual volume of the liquid at −7° as unity, it becomes 1·264 at +35·8, which gives 0·00489 as its coefficient of expansion per degree for the total range of pressure. It is therefore only about half as expansible as carbonic acid, whose coefficient is 0·010, and is not much more expansible than a gas. Comparing the density of liquid acetylene with that of liquid benzene, the latter is found to be almost exactly twice as great as the former at the same temperature; as, for instance, at 0° C. the density of the acetylene is 0·451, whereas that of the benzene is 0·899. The vapour density, however, of the benzene is three times as great, viz. 2·704.

Co-efficient of expansion of liquid Acetylene

Density as compared with Benzene

"The apparent compressibility in glass was determined by direct observation, the liquid being forced up in the capillary tube until the latter was completely full, and then the pressure gradually increased, and the diminution in volume read off at intervals of about 10 atmospheres up to about 180 atmospheres.

Compressibility of liquid Acetylene

"Curves were then plotted showing the volume at different pressures for the same temperature, and from these the coefficient of compression at any temperature and pressure was easily deduced.

"The following tables are constructed from the curves:

Tables of coefficients of compression of liquid Acetylene

1. Mean coefficients of compression of liquid acetylene at different temperatures. Range of pressure from 36·62 to 182·68 atmospheres:

Temp. of Acetylene.	Coeff.	Temp. of Acetylene.	Coeff.
35° C.	0·00085	16° C.	0·00050
28·6	0·00068	4·4	0·00038
22·5	0·00058	0	0·00025

2. Coefficients of compression at the same pressure but varying temperatures:

Temp. of Acetylene.	Atm. 70.	Atm. 95.	Atm. 120.	Atm. 160.
[1] 49° C.		0·00343	0·00169	0·00078
[1] 41		0·00138	0·00099	0·00076
35	0·00171	0·00113	0·00078	0·00065
28·6	0·00122	0·00083	0·00072	0·00050
22·5	0·00079	0·00065	0·00057	0·00047
16·0	0·00066	0·00050	0·00049	0·00035
4·4	0·00047	0·00042	0·00034	0·00032
0	0·00041	0·00036	0·00025	0·00029

3. Coefficients of compression at varying pressures and temperatures corresponding to the same volume:

	Vol.=97 cmm.		Vol.=92 cmm.	
Temp. of Acetylene.	Pressure.	Coeff.	Pressure.	Coeff.
[1] 49° C.	170·8	0·00080		
[1] 41	137	0·00085		
35	103·2	0·00093	175·8 atm.	0·00065
28·6	70·0	0·00120	137·8	0·00063
22·5			99·2	0·00065
16·0			59·5	0·00066
	Vol.=101 cmm.		Vol.=89 cmm.	
[1] 49	126·3 atm.	0·00128		
[1] 41	98·3	0·00132		
35	72·7	0·00167		
22·5			158 atm.	0·00054
16·0			115·6	0·00056
4·4			49·7	0·00058

Effect of temperature and pressure on compressibility

"It is evident from the above tables that acetylene is governed by the same laws as other compressible liquids; that is to say, its compressibility increases as the temperature rises, but diminishes as the pres-

[1] These two experiments were, of course, made above the critical point.

sure increases. For instance, at a pressure of 95 atmospheres it is three times as compressible at 35° C. as at 0° C.

"The volume being the same, the compressibility appears to be nearly the same at different temperatures, which is really due to the curves at high pressures running nearly parallel, thus introducing a corresponding difficulty in the estimation of small differences.

"On comparing the compressibility of liquid acetylene with the results obtained by M. Amagat (*Ann. Chem.*, 1877) in the case of benzene, it appears to be about seven times as compressible as the latter body at a temperature of 16° C., and under a pressure of 40 atmospheres. The comparison could not be carried out at higher temperatures, for whereas M. Amagat reaches a temperature of 100° C. with the benzene, I was not able to go beyond 35° C. with the acetylene."

Yield of gas from liquid Acetylene

Willson and Suckert[1] also determined the density of the liquid at 20·6° C., and find it to be 0·528; and further state that 1 volume of liquid acetylene at 17·8° C. yields 400 volumes of the gas at atmospheric pressure.

Explosions due to liquid Acetylene

When it was realized that acetylene could be liquefied with no more difficulty than carbon dioxide, a brilliant future seemed assured for the liquid; but, unfortunately, these hopes were soon dispelled by several very serious explosions of cylinders containing it, which took place in America and on the Continent.

As has been pointed out, acetylene is an endothermic compound, and when decomposed into its elements gives out nearly as much heat as the combustion of an equal volume of hydrogen to form water.

The detonation of Acetylene by means of Mercuric Fulminate

This characteristic of acetylene first investigated by Berthelot[2] led him to the discovery that it was possible

[1] *Journn. Franklin Inst.*, 138, 327.
[2] *Compt. Rend.*, 93, 613.

It consequently contains a large amount of stored up energy, and one might expect that a decomposition starting at one point in a given gas volume would spread spontaneously through the entire mass

to explode pure acetylene by firing in it a small charge of mercuric fulminate, and he devised an apparatus in which this experiment is now always carried out.[1]

The apparatus used by Berthelot

It consists of a glass tube A, of considerable strength, luted into a steel collar, the mouth of which is closed gas-tight by a plug F, which is kept in its place by a cap G, which fixes on to the collar of the glass tube with a bayonet joint. The plug F carries a small tube E E, through which passes a stout wire D sealed into it. The end of this wire, which is in the

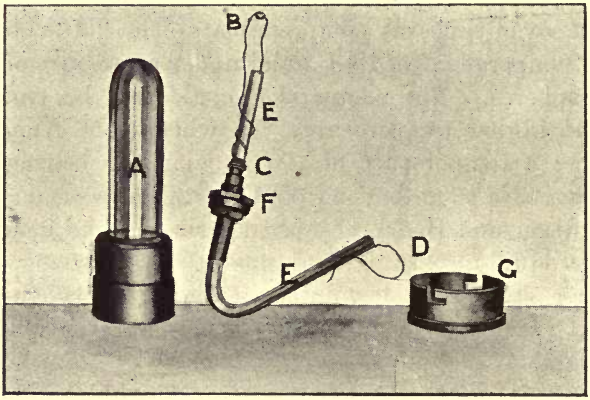


FIG. 14.

interior of the tube, is connected to a second wire by means of a piece of thin platinum wire, which, after being coiled round the outside of the capillary tube, is fixed in metallic contact with the plug at C, whilst a small cap B, containing 0·1 gr. of mercuric fulminate is attached to the thin platinum wire.

Method of performing the experiment

The glass tube is now filled with acetylene over the trough, and the tube with the cap passed up into it with the plug fixed in position, the cap being then placed over all and fixed by the bayonet joint.

[1] *Sur la force des matières explosives*, Paris, 1883, vol. i. 110.

On now passing a current through the wires the fulminate explodes and causes detonation of the acetylene, which takes place with a brilliant flash of light and the deposition of a cloud of black carbon. On again opening the apparatus under mercury and collecting the gases, it is found that the acetylene has practically all disappeared, and that nothing remains but hydrogen contaminated with small traces of carbon monoxide and nitrogen, produced by the explosion of

Result of the explosion

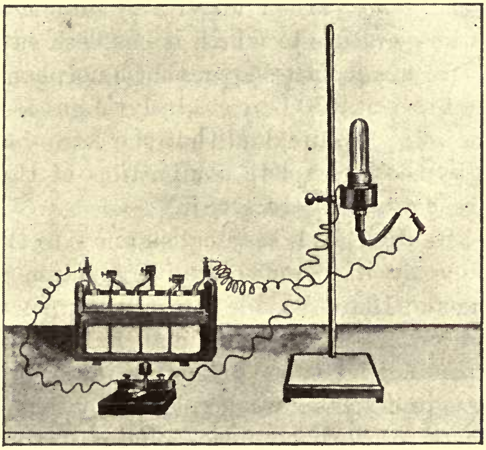


FIG. 15.

the fulminate, and it is clear that the acetylene under the influence of the explosive wave generated by the mercuric fulminate has decomposed into its constituents.

$$C_2H_2 = C_2 + H_2.$$

Rapidity of the explosion

"The reaction is so rapid that the small cartridge of thin paper which enveloped the fulminate will be found torn but not burned, even in its thinnest fibres, and this is explained if we note that the time during which the paper remained in the explosion centre was about $\frac{1}{30000000}$ of a second, according to the thickness

of the paper and the known data relative to the rapidity of this order of decomposition."

Condition of the liberated Carbon

"The carbon set free exhibits the same general conditions as that obtained in a tube at a red heat. It is mainly amorphous carbon and not graphite; it dissolves almost totally when treated several times with a mixture of fuming nitric acid and potassium chlorate. Nevertheless, treated in this way, it gives a trace of graphitic oxide, which proves that it contained a trace of graphite, produced, doubtless, by the transformation of the amorphous carbon under the influence of the excessive temperature to which it has been subjected.

Action of heat on amorphous Carbon

Berthelot [1] has in fact shown that amorphous carbon heated up to about 2,500° by electrolytic gas commences to change into graphite, and that the lamp-black precipitated by the incomplete combustion of the hydrocarbon also contains a trace of it.

The detonation of the gas at ordinary pressures only local

When attention had been called anew to the safety of acetylene by its commercial introduction in 1895, Maquenne and Dixon [2] made a research upon the explosion of endothermic gases, and found that when acetylene in a lead tube 10 metres in length and 3 centimetres in diameter was exploded by firing in it a charge of 0·5 gr. of mercuric fulminate, the decomposition was of a very local character, and that 0·5 m. from the detonating chamber 85·8 per cent. of the acetylene remained undecomposed; 1·0 m. from the detonating chamber 92·2 per cent. of the acetylene remained undecomposed; 5·0 m. from the detonating chamber 93·2 per cent. of the acetylene remained undecomposed; and that even when 1 gr. of the fulminate was used to start the decomposition, the deposit of carbon only extended 5 m. from the point of detonation, so that large quantities of acetylene still remained undecomposed.

[1] *Ann. Chim. Phys.*, 5th series, 29, 418.

[2] *Compt. Rend.*, 121, 424.

In 1896 Berthelot and Vielle[1] made a most important series of researches upon the explosive properties of acetylene, both in the gaseous and liquid condition, in which they state:

Berthelot and Vielle research on the explosive properties of gaseous and liquid Acetylene

"The industrial importance lately acquired by acetylene for lighting purposes has led to much research into the precise conditions under which its explosive properties are capable of being manifested, and has served consequently to point out the precautions necessary in its employment.

1. The Influence of Pressure

Under a constant atmospheric pressure, the decomposition started at any one point in acetylene does not extend to any great distance. Neither a spark, nor the presence of an ignited body, not even a cap of fulminate, exert any action beyond the neighbourhood of the region directly affected by the heat or percussion. Maquenne and Dixon[2] have published some interesting observations on this point. We have discovered, however, that this does not hold good when the pressure on the gas is increased to more than two atmospheres. The acetylene then manifests the ordinary properties of explosive mixtures.

The influence of pressure on the detonation of Acetylene

If decomposition is started at any one point by means of a fine iron or platinum wire raised to a white heat by the electric current, the decomposition spreads through the whole mass without any appreciable diminution. This phenomenon has been observed to take place in tubes 20 mm. diameter through a length of 4 m. This property can be brought near the lowest limit of the combustion of explosive mixtures under pressure; it is probably common amongst endothermic gases.

The propagation of explosion in Acetylene

[1] *Compt. Rend.*, 123, 523; *Ann. Chim. Phys.* (7), 11, 5.
[2] *Compt. Rend.*, 121, 424.

2. Decomposition of Gaseous Acetylene under Pressure

Apparatus used

In these experiments strong steel cylinders were used, such as are usually employed for the study of the laws of the development of pressures produced by explosives.

The fig. 16 represents a section of the apparatus, the cylinder having a capacity of about 49 cc. The length of the combustion chamber is 110 mm. The cylinder is provided at one end with a fireproof plug A, carrying a fine iron or platinum wire *a*, which can be raised to a white heat by means of an electric current. The other end of the cylinder is fitted with a crusher gauge B,

Measurement of the pressures developed

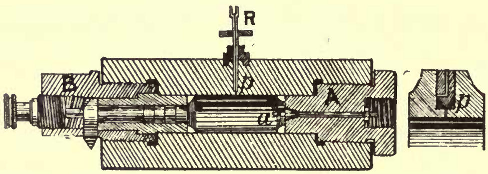


Fig. 16.

the piston of which being provided with a recording point, inscribes the force of its motion upon a revolving cylinder. This curve, when compared with the known factor for the compressed cylinder of metal in the crusher gauge, gives a correct estimate of the pressure at each moment of the combustion. By means of the tap R the cylinder can be connected with either an exhausting or condensing pump.

Measurement of the initial pressure

The initial pressure of the gas introduced into the cylinder is measured at absolute value, by means of a Bourdon manometer, which has been previously compared with Amagat's free piston manometer. The following table includes the pressures and the duration of the reaction, observed at the time of the ignition of the acetylene by means of the fine wire made red hot in the centre of the gaseous mass.

Table showing pressures and duration of the reaction

Number of Experiments.	Absolute Initial Pressure. Kgr.	Pressure observed soon after reaction. Kgr.	Duration of reaction in $\frac{1}{1000}$ of a second.	Comparison of the Initial and Final Pressures.
38	2·23	8·77		3·93
43	2·23	10·73		4·81
28	3·50	18·58	76·8	5·31
31	3·43	19·33		5·63
39	5·98	41·73	66·7	6·98
26	5·98	43·43		7·26
32	5·98	41·53	45·9	6·94
25	11·23	92·73	26·1	8·24
40	11·23	91·73	39·2	8·50
29	21·13	213·70	16·4	10·13
30	21·13	212·60	18·2	10·13

The final speed is still very much less than that of the explosive wave in an oxy-hydrogen mixture.

Products of the decomposition

After the reaction, if the crusher gauge end of the cylinder be opened, it will be found full of powdered carbon containing a trace of graphite—a sort of light agglomerated soot which takes the form of the receiver, and from which it can be withdrawn in a fragile mass. The gas left after the decomposition is found to consist of pure hydrogen. These results are similar to those observed in previous experiments.[1] The final pressure also, after cooling down, is found to exactly correspond with the initial pressure.

The decomposition then follows the theoretical formula—

$$C_2H_2 = C_2 + H_2.$$

The above table shows that under an initial pressure of about 21 kilos., a tension equal to half the tension of vapour saturated with liquid acetylene at a surrounding temperature of 20°, the explosion will increase the initial pressure tenfold.

Heat developed at the moment of decomposition

The temperature developed at the moment of decomposition can be estimated in the following manner: The heat produced would be about +58 calories, if the

[1] *Sur la force des matières explosives*, 1, 112 and 113.

carbon were liberated in the condition of diamonds; but for the production of carbon in an amorphous state, it would be reduced to + 51 calories. Moreover, the specific heat at constant volume of hydrogen, H_2, at a high temperature is represented by the formula—

$$4{\cdot}8 + 0{\cdot}0016\ (t. = 1{,}600).$$

Taking the specific heat of carbon as determined by Vielle for high temperatures, the value for $C_2 = 24$ grs. will be

$$8{\cdot}4 + 0{\cdot}00144\ t.$$

After combining these numbers and the equation of the second degree corresponding, the temperature of the decomposition at constant volume would be

$$t. = 2{,}750^\circ \text{ about.}$$

Pressure developed

Thus the pressure developed would be eleven times as great as the initial pressure, which agrees very well with the results observed under the initial pressure of 21 kilos., a pressure high enough, without doubt, to allow of the effects of the cold produced by the walls to be neglected.

With a lower pressure the cold interferes, reducing the temperature, of which the rate of the reaction is a function, and the same variable action follows.

Effect of pressure on the rate of decomposition

Thus the duration of the decomposition of acetylene rapidly decreases as the pressure is increased, not only on account of the diminished influence of cold, but also as the effect of condensation. Besides, it must be noticed that the ratio of the initial to the developed pressure is here calculated according to the law for perfect gases.

This ratio ought to rise more and more beyond the preceding limits when the initial pressure is increased, owing to the increasing compressibility of the gas, which produces a more rapid growth in the density of

the charge than in the pressure in proportion as the gas approaches its point of liquefaction. At the same time that the pressure increases the rate of the reaction is also increased. This is accelerated by the gaseous condensation, and tends more and more to approach the relative point of the liquid state.

Such are the general facts established by the researches of Berthelot, particularly by his experiments on the formation of ethers. Liquid acetylene affords fresh points for consideration.

3. Decomposition of Liquid Acetylene

The explosion of liquid Acetylene

The reaction takes place in just the same way in liquid acetylene, even when it is started by simple ignition by means of an incandescent wire. In a steel bomb of 48·96 cc. capacity, charged with 18 grs. of liquid acetylene—weight estimated after the weight of carbon had been taken—a pressure of 5,564 kilos. per square cm. is reached. This experiment would seem to attribute to acetylene an explosive force of 9,500, *i.e.* almost equal to that of guncotton. In the interior of the bomb is left a block of carbon agglomerated by the pressure, and having a brilliant and conchoidal fracture. This carbon, according to Moissan, contains only traces of graphite, a statement agreeing with previous results.

Explosive force of the liquid

Condition of the Carbon separated during explosion

The decomposition of liquid acetylene by simple ignition is comparatively slow. In one experiment, No. 41, for which the density of the charge was close on 0·15, the maximum pressure of 1,500 kilos. per square cm. was reached in $\frac{9}{1000}$ of a second. The curve registered on the revolving cylinder indicated a static working of the crusher apparatus, following two distinct stages. The one, taking about the thousandth part of a second, raised the pressure to 553 kilos.; the other, slower, increased the pressure to 1,500 kilos. at the end of $\frac{9}{1000}$ second. The two stages correspond,

Rate at which the maximum pressure is attained

probably the one to the decomposition of the gaseous portion, the other to that of the liquid. The same characteristics of discontinuity have been found in many curves of the decomposition of gaseous and liquid mixtures. As a result of the foregoing, every time a gaseous or liquid charge of acetylene under pressure, and, above all, at constant volume, is submitted to an action capable of producing the decomposition of one of those points, and consequently a corresponding local elevation of temperature, the decomposition will be capable of being spread through the whole mass. It now remains to determine the conditions under which this decomposition into elements can be obtained.

Two stages noticed in the explosive decomposition of liquid Acetylene

4. The Effects of Shock

Conditions leading to the decomposition of Acetylene in the liquid state

We have submitted to shock—either by allowing them to fall from a height or by blows from a hammer—steel cylinders of about 1 litre capacity, charged, some with gaseous acetylene compressed at 10 atmospheres and others with liquid acetylene, at a charge density of 0·3—3,000 gr. to the litre.

Effect of shock

1. Repeated falls from a height of 6 metres on to a massive steel anvil gave rise to no explosion.

2. The crushing of the same receivers under a hammer of 280 kilos. falling from a height of 6 metres, produced neither explosion nor light in the case of gaseous acetylene under a pressure of 10 atmospheres. With liquid acetylene in the experiment the shock was followed after a short interval by an explosion. This phenomenon appears attributable not to the pure acetylene, but to the ignition of the explosive mixture of acetylene and air formed in the moment of time which follows the rupture of the cylinder. The ignition is no doubt brought about by the sparks produced by the friction of the edges of torn metal. An inspection of the cylinder confirms this view. It has

Result of bursting the cylinder under a hammer

simply been broken by the shock, without flying to pieces or the deposition of carbon, which proves that the acetylene has not been decomposed into its elements, but has simply burnt under the influence of the oxygen of the air. A similar result following the violent fracture of a cylinder charged with combustible gas has been noticed under many circumstances, especially in the breaking of hydrogen cylinders charged at many hundred atmospheres pressure.

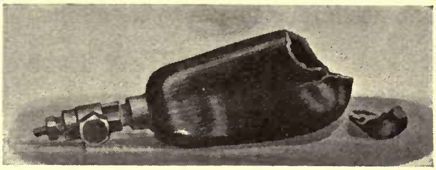


FIG. 17.

Result of the impact of a bullet

3. A cylinder of wrought iron, containing gaseous acetylene under a pressure of 10 atmospheres, bore without explosion the impact of a bullet which had sufficient velocity to pierce the front and dent the back of the cylinder.

Detonation of liquid Acetylene by a charge of Mercuric Fulminate

4. Detonation by a fulminate cap. An iron cylinder containing liquid acetylene was provided with a thin wad for the introduction of a charge of 1·5 gr. of fulminate of mercury in the centre of the liquid. The whole exploded with violence after the ignition of the fulminate. The broken pieces of the cylinder present

FIG. 18.

the same appearances as are observed when ordinary explosives are used.

The fragments are coated with carbon arising from the decomposition into its elements.

5. Heat Effects

Effect of heat on liquid and gaseous Acetylene

Many causes leading to local rise of temperature seem to have been observed in the industrial operations for the preparation or employment of acetylene.

Overheating during generation

1. The first is the result of the action of small quantities of water on the calcic carbide in a closed apparatus. Pictet gives an account of an accident due to this cause. It needs great care to prevent the action of the water on the carbide causing a local rise in temperature which may reach a white heat, and this at any point, as has been experimentally shown, would suffice to produce an explosion of the whole mass of compressed gas. The local rise in temperature also leads to the formation of styrolene, benzene, naphthalene, and other polymerisation products of acetylene.[1] This action also gives rise to heat, and the temperature consequently rises to the point at which the decomposition of acetylene into its elements becomes complete and even explosive.

Overheating from too sudden compression

Elevation of temperature on too suddenly opening the valve of a cylinder

2. Other causes of danger in industrial operations result from hasty compression when charging the cylinders with gas, as well as the adiabatic compression which accompanies the too sudden opening of an acetylene receiver fitted with a pressure-reducing valve or any other reservoir of small capacity. Experiments on cylinders of compressed carbonic acid have shown that the sudden opening of the valve gives rise to an elevation of temperature capable of carbonising chips of wood placed in the interior.

3. A violent shock due to an external cause and capable of smashing the cylinder does not, of itself,

[1] *Ann. Chim. Phys.*, 4; xii. 52, 1867.

seem to directly cause the explosion of acetylene, but the friction of the metallic fragments against each other or against external objects is capable of igniting the explosive mixture formed by the mixture of the acetylene with the air following the rupture of the cylinder.

In conclusion it seems both useful and necessary to define more clearly from the theoretical and experimental point of view the explosive nature of acetylene, and to point out from the practical side of the question accidents likely to happen in its employment, but the inconveniences are not of such a nature as to outweigh the advantages or limit the use of this gas. It is easy to guard against these risks by various expedients shown by experiment; such as, on the one hand, for the experimentalist to avoid too rapid a discharge of the compressed gas from the governors; and, on the other, to take care to fully absorb the heat produced by the compression and reactions in the interior of the apparatus, so as to prevent any noticeable rise in the temperature."

Precautions to be taken in making and using liquid Acetylene

The result of the numerous explosions with liquid acetylene, and the researches which showed that at pressures above two atmospheres acetylene became an explosive capable of detonation without admixture with air, led to the prohibition of liquid acetylene in England, and the use of gas at pressures above 100 inches of water over atmospheric pressure being placed under the regulations of the Explosives Act.

Prohibition of liquid Acetylene in England

Continuing their researches upon the starting and propagation of explosion in acetylene, Berthelot and Vielle[1] say :—

"We have shown in a previous publication[2] that the decomposition of acetylene under normal pressure does not spread beyond the point at which it was started, but at and above twice the normal pres-

Further researches by Berthelot and Vielle

[1] *Ann. Chim. Phys.* (7) 13, 24. [2] *Ibid.* (7) 11, 5.

sure it exhibits the usual properties of explosive mixtures. Under the same pressure, however, this aptitude for propagation depends on the exciting conditions and the external influence of cold. Between the conditions under which an explosion is inevitably produced, and those under which one is not obviously probable, an interval exists, and it is this interval which we shall try to define.

In view of actual practical applications, it will be as well to define the limits of pressure above which the explosive properties of acetylene become dangerous.

The limits of pressure above which the explosive properties of Acetylene become dangerous

We have studied two methods by which the explosion may be started: by the incandescence of a metallic thread; by a cap of fulminate of mercury.

The first method corresponds in practice with intense and local heating, which may be produced either by the attack on a mass of carbide by small quantities of water, or by energetic friction between the metal portions in contact with the gas, such as tightening the nut on the fastening points.

The methods employed for starting explosion

The second method may be produced by the combustion of small quantities of very explosive acetylides, such as might be formed by the acetylene on contact with copper or its alloys in presence of ammonia.

The influence of temperature on propagation

We have made experiments to show the influence of cold on the propagation of explosion in volumes of gas inclosed in vessels, the diameter of which equalled the height, the capacity varying from 4 to 25 litres; and sometimes in metal tubes of 22 mm. diameter and 3 metres in length, in which the influence of cold surfaces was considerable.

Propagation in large receivers.— The following tables summarise the results obtained. For each experiment, the receiver, after being exhausted, was filled with gas from a metal cylinder containing liquid

acetylene; the receiver was exhausted a second time, and again filled with gas under a pressure which was measured by a mercury manometer. The decomposing force was produced successively in two ways, by an incandescent metal wire, and by a cap of fulminate placed in the centre of the gaseous mass.

The propagation of explosion in large receivers

Steel Receiver of 4 Litres.

Initial pressure in centimetres of mercury.	Firing by an incandescent wire.	Firing by a charge of 0·1 gr. mercuric fulminate.
cm. cm.		
76 and 17		10 expmts., no propagation.
76 „ 24	1 expmt., no ignition	4 „ 1 ignition.
76 „ 30·5	1 „ „	3 „ 2 ignitions.
76 „ 38	4 expmts., „	3 „ 2 „
76 „ 46	4 „ „	
	Two iron and two platinum wires.	
76 and 52	6 experiments, no ignition.	
76 „ 61	5 „ 1 „	
76 „ 70	7 „ 4 ignitions	

Results

Glass Vessel of 25 Litres.

Initial pressure of gas in cc. of mercury.	Firing by an incandescent wire.	Firing by a charge of 0·1 gr. of mercuric fulminate.
76		1 expmt., no ignition.
76 and 7·5	3 expmts., no ignition	2 expmts., no ignition.
76 „ 10·5		1 expmt., no ignition.
76 „ 16·8	1 expmt., no ignition	1 „ „
76 „ 24	2 expmts., no ignition	2 expmts., no ignition.
76 „ 38		1 expmt., ignition and rupture of receiver.

These experiments show that it is impossible with a fixed method of starting the action to define an absolutely fixed critical pressure below which propagation would be impossible, and above which it would be equally certain. The transition is a progressive one following a scale of pressures to which the increasing probabilities of explosion correspond.

Conclusions arrived at

This does not apply only to acetylene. In all explosives the phenomena of propagation, whether by

The characteristics of propaga-

tion same as with other explosives

shock or other influence, present the same characteristics, and the conditions assuring certain explosion are always widely different to those which will assure positive insensibility; in the interval come dangerous zones, where one can only define the probability of explosion.

The fulminate cap three times as powerful in starting explosion as the incandescent wire

The rapid decrease in these possibilities leads one in the present case to regard a pressure below 52 cm. of mercury, or 7 metres of water, when using an incandescent wire, as not dangerous. So also a pressure below 17 cm. of mercury, or 2·30 metres of water, when using the cap of fulminate, so that this latter is three times as powerful an agent as the former.

The experiments carried out in the 25 litre receiver show that the capacity of the vessel has no appreciable influence.

Result of the decomposition

Ignition gives rise under all pressures to the production of voluminous clouds of carbon of great density, which coat the walls of the receiver, partially filling it; at the same time the metallic receiver became heated. When the ignition does not spread, only slight fumes are observable, which are deposited in the shape of a mist, and are only visible in the glass receivers. In these experiments a sufficiently small cap must be used in order to obviate any appreciable modification of the general pressure of the receiver, and thus ensure an initial stimulus.

Influence of metal tubes on the propagation of the explosion

Propagation in metal tubes. It was difficult to foresee the influence which the tubulure form of receiver would exert upon the phenomena of propagation.

It would naturally be supposed that when using the incandescent wire cold would be opposed to propagation, and, on the other hand, that the use of the fulminate cap would increase it, because of the local pressure developed in the centre of the region occupied by the fulminate charge. The experiments

Size of tube used

were made with a steel tube of 22 mm. diameter and

3 metres long, closed at one end by a metal plug, and at the other by a strong glass bell.

Result of the experiments

These experiments only furnished negative results at an initial pressure of 76 cm. of mercury, three times higher than those in which propagation had been observed in vessels of the same capacities, the breadth of which was considerable.

The capacity of the tube employed was about 1 litre, and the first experiments were made with a charge of 0·025 gr. so as to preserve the ratio of the weight of the charge to that of the total volume, since this ratio had been established at the time of the experiments with the 4 litre receiver. Propagation not being produced, we then employed, in spite of the reduced volume of the tube, the same cap of 0·1 gr. as had already been experimented with. This time also with pressure not above 1 atmosphere, and 2·06 mg. per square cm.; no propagation was observed. The explosion of the cap taking place, either against one of the extremities of the tube or at a distance of 30 cm., produced only a light cloud of carbon in its immediate neighbourhood. The result of these experiments is given in the following table:—

Result of increasing the charge of fulminate

Steel tube 22 mm. diameter, 2·89 long, capacity, 1·098 litre.

Results of experiments

Initial pressure.	Firing.	Observations.
76 and 17	0·025 gr. fulminate	1 experiment, no propagation, carbon coating on cork.
76 „ 30·5	0·025 „ „	1 experiment, no propagation, carbon coating on cork.
76 „ 38	0·025 „ „	1 experiment, no propagation, carbon coating on cork.
76 „ 24	0·1	1 experiment, no propagation, carbon coating on cork.
76 „ 38·8	0·1 cap placed near extremity	1 experiment, no propagation, carbon coating on cork.
76 „ 61	0·1	1 experiment, no propagation, carbon coating on cork.
76 „ 76	0·1	
76 „ 38	0·1 cap at 30 c.m. from extremity	1 experiment.
76 „ 76	0·1	3 experiments, no propagation, carbon cloud on cork.

In the three last experiments ignition by a red-hot wire had been previously tried without result."

In January, 1899, Georges Claude[1] made a communication to the Académie des Sciences on the explosibility of acetylene at low temperatures.

Explosibility of Acetylene at low temperatures

The solubility of acetylene in acetone increases with extraordinary rapidity with fall of temperature, especially as the point of solidification of the acety-

FIG. 19.

lene is approached. At $-80°$ C at ordinary atmospheric pressure one volume of acetone dissolves more than 2,000 volumes of acetylene, whilst the solution occupies four to five times the volume of the original acetone, and a platinum wire may be heated to bright redness in this solution without any explosion taking place. In the same way liquid acetylene cannot be exploded by a red-hot platinum wire at $-80°$ C., at

[1] *Compt. Rend.*, 128, 303.

which temperature it has a vapour tension of 1·3 atmospheres. From these experiments the author comes to the conclusion that acetylene can with perfect safety be liquefied by using a pressure of 1·3 atmospheres at −80° C.

Safety in liquefaction assured at —80° C.

Solid Acetylene

When liquid acetylene is sprayed out from a cylinder, Fig. 19, so much heat is absorbed by the conversion of the liquid into a gas, that some of the liquid is frozen into a snow-like solid, Fig. 20, in the same way as carbon dioxide, and in a lecture before

Fig. 20.

Temperature of solidification

the Franklin Institute, Willson and Suckert[1] showed this, and stated that acetylene cooled below −81° C. becomes solid, and the snow so formed evaporates but slowly, floats on water, and when ignited burns with a heavy smoky flame.

Later in 1895, Villard[2] gave the melting-point of solid acetylene as −81° C.

Dewar's researches on the spectrum of Acetylene

The spectrum of hydrocarbons has been worked upon by many observers, and the general view is well

[1] *Journ. Franklin Instit.*, 139, 327.
[2] *Compt. Rend.*, 120, 1262.

summarised by Liveing and Dewar,[1] who in a paper published in 1880 say:—

The Hydrocarbon spectra

"In a Memoir on 'The Spectra of Metalloids'—*Nova Acta Reg. Soc. Upsal.*, III. ix.—Angström and Thalèn have made a careful analysis of the different spectra assigned to carbon. They distinguish four sets of groups of shaded bands produced under different circumstances, which they define, besides the line spectrum which they ascribe to carbon itself. Of these four sets of bands, two sets, situated at the extremities of the spectrum, they show to be produced in the combustion of cyanogen, a third to be common to all the hydrocarbons, and the fourth to be produced by carbonic oxide. The first two sets, the third, and the fourth sets respectively, they observed to be produced also in the electric discharge between carbon electrodes, according as it took place in nitrogen, hydrogen, or oxygen. Their observations on this subject appear almost conclusive. Nevertheless other observers have since their publication maintained different opinions.

Characteristic bands in the Hydrocarbon spectrum

The spectrum of hydrocarbons burning in air has been repeatedly described; first by Swan in 1856, and afterwards by Atfield, Watts, Morren, Plücker, Boisbaudran, and others, and has been given in detail by Piazzi Smyth. The characteristic part of this spectrum consists of four groups of bands of fine lines in the orange, yellow, green, and blue respectively, and we refer hereafter to these as the hydrocarbon bands. These four groups, according to Plücker and Hittorf, also constitute the spectrum of the discharge of an induction coil in an atmosphere of hydrogen between carbon electrodes. They are also conspicuous in the electric discharge in olefiant gas at the atmospheric and at reduced pressures.

* * * * *

[1] *Proc. Roy. Soc.*, 30, 152.

The contention of Ångström and Thalèn is that the channelled spectra of the hydrocarbon and cyanogen flames are the spectra of acetylene and cyanogen and not of carbon itself, and that in the flame of burning cyanogen we sometimes see the spectrum of the hydrocarbon superposed on that of the cyanogen, the latter being the brighter; and that in vacuum tubes containing hydrocarbons the cyanogen spectrum observed is due to traces of nitrogen."

Spectrum given by the arc in Hydrogen

After describing a very beautiful series of experiments, they say: "In the next place the green and blue bands characteristic of the hydrocarbon flame are well seen when the arc is taken in hydrogen; but though less strong when the arc is taken in nitrogen or in chlorine, they seem to be always present in the arc, whatever the atmosphere. This is what we should expect if they be due, as Ångström and Thalèn suppose, to acetylene, for we have found that the carbon electrodes always contain, even when they have been long heated in chlorine, a notable quantity of hydrogen.

In the flames of carbon compounds they by no means always appear; indeed, it is only in those of hydrocarbons, or their derivatives, that they are well seen. Carbonic oxide and carbon disulphide, even when mixed with hydrogen, do not show them; and if seen in the flames of cyanogen, hydrocyanic acid and carbon tetrachloride mixed with hydrogen, they are faint, and do not form a principal or prominent part of the spectrum. This is all consistent with the supposition of Ångström and Thalèn. The fact that the bands are not produced even in the presence of hydrogen, when it is not present in the flame in the form of a compound with carbon, is very significant; for we know that acetylene is present, and can easily be extracted from the flame of any hydrocarbon, and that it is formed as a proximate product of decom-

position of hydrocarbons by the electric discharge, but we have no evidence that it is producible as a product of direct combination of carbon with hydrogen at the comparatively low temperature of a flame such as we have mentioned.

Acetylene present in the blowpipe flame

The hydrocarbon bands are best developed in the blowpipe flame; that is, under conditions which at first sight appear unfavourable to the existence of acetylene in the flame. We have, however, satisfied ourselves by the use of a Deville's tube that acetylene may readily be withdrawn from the interior of such a flame, and from that part of it which shows the hydrocarbon bands most brightly.

The question as to whether these bands are due to carbon itself or to a compound of carbon with hydrogen, has been somewhat simplified by the observations of Watts and others on the spectrum of carbonic oxide. There is, we suppose, no doubt now that the compound has its own spectrum quite distinct from the hydrocarbon flame spectrum. The mere presence of the latter spectrum feebly developed in the electric discharge in compounds of carbon, supposed to contain no hydrogen, appears to us to weigh very little against the series of observations which connect this spectrum directly with hydrocarbons."

Other papers which contain matter bearing upon this point are Liveing and Dewar, *Proc. Roy. Soc.*, 30, 490; *ibid.*, 34, 418; Berthelot and Richard, *Compt. Rend.*, 68, 1546; Wuellner, *Pogg. Ann.*, 2, 14, 355; and Haselberg, *ibid.*, 2, 7, 691.

Electrical relations of Acetylene

The electrical relations of acetylene have not been very fully studied, but Bredig and Usoff[1] state that the electric conductibility of an aqueous acetylene solution being very low, acetylene will be a very weak electrolyte, and one of the weakest acids. Therefore its salts must be completely dissociated in aqueous

[1] *Ztsch. Electrochem*, 3, 116.

solutions, and the reaction of calcium carbide and water, —and the existence of silver suboxide, Ag_2O, in silver acetylene agree with that view. In a concentrated aqueous solution of calcium chloride, calcium carbide is fairly stable.

Jones and Allen[1] have also worked at this subject.

[1] *American Chem. Journ.*, 18, 375, 623.

CHAPTER IV

THE CHEMICAL REACTIONS OF ACETYLENE

Berthelot's researches on the action of heat on Acetylene

THE action of heat upon acetylene was first studied by Berthelot[1] in 1866, who found that: "On heating pure acetylene in a curved tube over mercury to a temperature sufficient to soften hard glass, the volume of the gas decreases, and at the same time tarry products make their appearance.

The formation of liquid and solid products

In one experiment at the end of half an hour 97 per cent. of the original acetylene had disappeared, leaving only 3 per cent. unchanged, whilst almost all the carbon and hydrogen of the acetylene are found in the liquid and solid products of the reaction. These latter consist of various carburetted polymers of the acetylene, such as benzene, which is the chief product, $3C_2H_2 = C_6H_6$; styrolene, $4C_2H_2 = C_8H_8$, etc.

Formation of Naphthalene

The residual gas consists principally of hydrogen, containing 2 per cent. of ethylene and a little ethane, and in addition there is a trace of naphthalene, and a small quantity of carbon corresponding to the hydrogen which constitutes the greater part of the gaseous residue.

Effect of a red heat on Acetylene

The effect of a higher and more prolonged temperature on acetylene has also been studied. This gas, when passed through a red-hot porcelain tube, decomposes almost entirely into carbon, which is deposited, and hydrogen, which is set free; a trace of acetylene,

[1] *Ann. Chim. Phys.*, 4, 9, 446.

however, remains, and a small quantity goes to form naphthalene, which crystallises,

$$5C_2H_2 = C_{10}H_8 + H_2,$$

and an almost imperceptible trace of tar, which is condensed, whilst some ethylene and methane are also formed and pass off with the hydrogen, constituting about one-tenth of the resultant gas.

Influence of dilution upon the action

// These experiments prove that acetylene decomposes at a red heat. When, however, acetylene is largely diluted with an inert gas, it is more stable than any other gaseous hydrocarbon. //

The decomposition of acetylene varies entirely according as the gas is acted upon *per se* or in the presence of other bodies.

Action of Carbon on the decomposition

For instance, in the presence of carbon which has been quenched under mercury it has been found that the disappearance of the gas is slightly more rapid than when the gas is used by itself. The products, however, are different; the volume of the gas hardly changes, whilst the gaseous residue consists of almost pure hydrogen. In other words, // in the presence of carbon a gaseous hydrocarbon resolves itself into its elements. This influence of carbon deserves further attention, as its presence is almost inevitable in all the heat reactions in which acetylene is produced. // The almost complete decomposition of acetylene at a red heat appears to be principally determined by the carbon deposited in the tubes. To explain its first formation, it must be admitted that the decomposition of acetylene at a red heat begins in the same way as at a lower temperature; that is, by successive polymeric condensation, followed by the resolution of the last polymers into their elements. //

The formation of Carbon during the decomposition by heat of Hydrocarbons

The influence of Iron on the decomposition by heat of Acetylene

Of all the metals which have been tried, iron exhibits the most interesting action, producing the complete decomposition of acetylene at a lower temperature, and at a greater rate, than when the

experiment is made with the gas alone; and as the result, carbon and hydrogen equivalent to about half the acetylene decomposed are formed together with certain empyreumatic hydrocarbons unlike those formed by the action of simple heat on the same gas.

Influence of Nitrogen on the decomposition

Acetylene, when mixed with its own volume of nitrogen, carbon dioxide, methane or ethylene, is decomposed with less rapidity than by itself, and without appearing to give rise to any special phenomena. In each case the quantity decomposed is proportional to the duration of the heat.

Influence of Hydrogen

Acetylene, when mixed with an equal volume of hydrogen, acts in a similar manner as with other diluents, *i.e.* decomposes rather more slowly than when by itself. It also gives rise to a greater proportion of ethylene, the hydrogen entering into combination with the acetylene—

$$C_2H_2 + H_2 = C_2H_4.$$

The formation of Benzene due to direct combination of the Acetylene molecules

The direct formation of benzene in such large quantities is not comparable with ordinary phenomena of decomposition, as it does not arise from the immediate destruction of the affinity binding the carbon and hydrogen, but is effected by a very different process, which is by no means incompatible with the great stability of acetylene. What is effected by the heat is not a decomposition, but, on the contrary, a combination of the highest order, developed by the reciprocal union of several molecules of acetylene—

$$3C_2H_2 = C_6H_6.$$

The same process seems to occur in a great number of heat reactions, though they are rarely so marked as in the case of acetylene.

The tendency shown by acetylene to form polymerised hydrocarbons seems a natural consequence of its composition.

Acetylene can combine with hydrocarbons in general,

and particularly with a hydrocarbon of similar composition, such as benzene. When these condensation products are exposed to the influence of a high temperature, say a red heat, they soon return to their original form, and fix their own rate of condensation and decomposition without returning to their initial state, because the changes which must be completed to reproduce this state are not effected in one way only. Hydrogen and the more condensed hydrocarbons are first formed, the latter becoming more and more rich in carbon, showing the production of naphthalene at the expense of the acetylene, and then comes carbon containing traces of hydrogen, representing the limit of this progressive condensation.

Combination of Acetylene with other Hydrocarbons

Influence of heat on the condensation products

Course taken by the heat actions

Carbon and hydrogen appear, then, to be the ultimate result of the decomposition, not of acetylene itself, but of the polymerisation products derived from it. The carbon also, when once produced, seems to exert an action of its own in resolving by its contact the acetylene into its elements, an action which can be explained as follows: at the same temperature as that at which highly-condensed hydrocarbons have the power of combining with acetylene with separation of hydrogen, carbon reacts on this hydrocarbon, uniting with its carbon and also giving rise to the liberation of hydrogen.

Carbon and Hydrogen the ultimate products of decomposition

Cause of the action of Carbon in the decomposition of Acetylene

Be that as it may, the decomposition of acetylene takes place in two successive stages—polymerisation, followed by the resolution of the polymers into their elements.

Such are the facts and theories which enable us to understand the decomposition of acetylene by heat."

In 1894, Lewes[1] tried the effect of passing acetylene through a heated tube under the following conditions: a platinum tube, 2 mm. in diameter and about 40 cm. in length, was used; and in order to

Lewes' experiments on the action of heat on Acetylene

[1] *Proc. Roy. Soc.*, 55, 90.

accurately measure the temperature to which the gas in the tube was heated, the following arrangement was devised:

Apparatus used

Acetylene was collected in a gasholder, and, after passing over calcium chloride to dry, it entered the platinum tube. In this tube a platinum and platinum-rhodium couple was arranged in the following fashion:

Measurement of temperature

The two wires were twisted together for a length of 3 mm., and the wires on either side of the twist were then passed through thin glass tubes, which were fused on to them. Having been in this way coated with glass, so that only the twist was exposed, they were

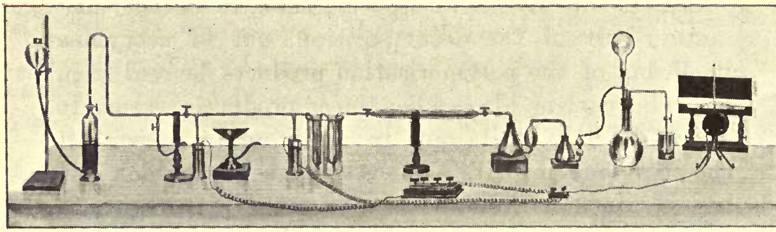


Fig. 21.

passed through the platinum tube, the glass insulating the wire from the tube, and also keeping the thermo-junction in such a position that it registered the temperature of the gas in the tube, not that of the wall of the tube.

To each end of the platinum tube glass T-pieces were fitted, down the stems of which the wires passed to mercury seals; from the metal seals conducting wires led to the resistance coils, the key and a reflecting galvanometer. The products, after leaving the platinum tube, passed through a U-tube cooled in ice and salt, in order to condense any liquids, and then through a collecting tube, from which the sample of gas for analysis was taken; thence to Volhard ab-

Collection of the products of condensation

sorption flasks, containing ammoniacal silver nitrate, for the estimation of acetylene, the flow of gas throughout the apparatus being regulated by means of the aspirator bottle.

Analysis of Original Gas.

Acetylene	94·28
Oxygen	1·12
Nitrogen	4·60
	100·00

The gas was then passed through the platinum tube, 25 mm. of which was heated to a temperature of 1,000° C.

Analysis of the gaseous products of the decomposition

Analysis of the Heated Gas.

Acetylene	25·95
Other unsaturated hydrocarbons	61·97
Saturated hydrocarbons	3·21
Carbon monoxide	1·01
Oxygen	0·38
Hydrogen	1·50
Nitrogen	5·98
	100·00

Solids and liquids formed

Carbon and Oil formed per 100 cc. of Gas.

Oil	0·095	grm.
Carbon	0·018	„
Volume before heating	309	cc.
„ after „	174·2	„

showing that, under these conditions, nearly three-quarters of the acetylene had undergone polymerisation.

The formation of Ethylene

The unsaturated hydrocarbons consisted chiefly of ethylene, with some benzene vapour, the ethylene having probably been formed by the direct combination of acetylene and hydrogen, an interaction first noticed by Berthelot—

$$C_2H_2 + H_2 = C_2H_4.$$

This also accounts for the small quantity of free hydrogen found on analysis, which, having regard

to the amount of carbon deposited, should have been considerably higher.

Haber's researches

Haber and Oechelhaeuser,[1] in 1896, also tried the effect of heat on acetylene, and give the following account of the form of apparatus employed:

"A uniformly high temperature, which may be kept absolutely constant or varied with precision, is not readily obtainable by processes of combustion. Attention was therefore directed to the electric furnace, of which there are two typical patterns. The arc pattern has already been used by Moissan in investigating phenomena of the chemistry of gases, but it is only suitable for very high temperatures. The heating of a constant resistance, which is the principle of the other pattern, was more suited for application in these researches. This type of furnace was readily adapted to the purpose; the heated conductor was made tubular, and the stream of gas passed through it. The conductor may be either of platinum or platinum-rhodium or of carbon. The former is best, so long as its relatively low melting-point is not attained, as it does not undergo change in air. In either case the walls of the conductor are not impermeable to gas, and, for quantitative experiments, a thin-walled porcelain tube was passed through the platinum conductor. Tubes of the No. 7 size, from the Royal Berlin Porcelain Works, could be used at any temperature below that at which the platinum conductor melted. With the carbon conductor qualitative experiments only could be made by passing the gas under pressure through the conductor itself. Some gas then escaped through the walls of the conductor.

Method of heating

Construction of the apparatus employed

The platinum furnace was made by rolling a piece of sheet platinum 0·05 m.m thick, 400 mm. long, and

[1] *Experimental-Untersuchung über Zersetzung und Verbrennung von Kohlenwasserstoffen* (Muenchen, 1896), pp. 43, 71.

55 mm. wide, into a tube. To each end of the sheet of platinum was soldered a sheet of copper 1 m. in thickness, of such dimensions that when the platinum sheet with the copper ends was formed into a roll of one turn, there remained at each end copper flaps 50 mm. wide and 40 mm. deep. These flaps, dipping into mercury in iron cups, served to convey the current to the platinum tube. A porcelain or glass tube, protected externally by a thin coating of asbestos paper, was then pushed through the platinum conductor, the middle part of which was wrapped in several turns of asbestos paper. This wrapping of the middle of the platinum conductor with asbestos prevents the loss of heat from that part, and it may thus be brought to a white heat whilst the uncovered end portions do not even glow. The furnace was inclined slightly to permit tar to flow away, and it was supported by fire-bricks, so that it did not bend of its own weight as it became hot. The iron cups were put at the necessary heights for the copper flaps to dip into them, and they were two-thirds filled with mercury, which was then covered by a thin layer of water.

Arrangements for heating the tube through which the Acetylene was passed

The conducting wires from the battery of accumulators were clamped to these cups. Two batteries were available—one of 36 elements of 36 ampère-hours capacity, and the other of 36 elements of 160 ampère-hours. The first, coupled in groups of 4 cells, gave a choice of 8, 24, or 72 volts; the second, in groups of 6 cells, gave a choice of 12, 24, 36, or 72 volts. The conducting wires were chosen of such diameter that they caused practically no loss of potential. The resistance of the furnace was about 0·06 ohm at 1,000° C., and therefore the small battery of 8 volts gave a current of 120 ampères, and the large one at 12 volts 200 ampères. These currents were too powerful for producing temperatures up to about

The source of the Electrical power used

1,200° C. A resistance piece, formed of two parallel brass tubes connected at their lower ends, was therefore used. Water under constant pressure circulated through the tubes, and the resistance was found to be 0·07 ohm. By means of a copper slide on the tubes this resistance could be lessened by any desired amount. This resistance piece served, when coupled with the small battery at 8 volts, to give currents of 60 to 110 ampères. With the larger battery three such resistance tubes were used. After the resistance piece, an ampèremeter was placed in the circuit.

The measurement of the temperatures employed

For measuring the temperatures attained in the tube of the electric furnace during the experiments, a Le Chatelier thermo-couple was used—after standardizing at the Imperial Physico-Technical Institute. For measuring the electromotive force any delicate galvanometer may be used, provided that its resistance is so great that the total of all losses of tension between the junction and the instrument is quite small compared with the difference of potential between the two terminals of the galvanometer. Le Chatelier used one of d'Arsonval's galvanometers, which had a very high resistance, and this was the instrument employed in this series of researches.

It would have needed too much time and care to carry out the measurement of the electromotive force by means of the compensation method whilst the decomposition was going on. It was therefore necessary to determine the value of the beats of the d'Arsonval galvanometer. This was done by observing the beat produced by the electromotive force which corresponded to a certain temperature, according to the determinations of the Imperial Institute, when such electromotive force was applied at the terminals of the galvanometer.

All that then remained to be done was to devise some protection for the thermo-element against the

hot gases in the furnace. A thin-walled glass or porcelain capillary tube was drawn through the furnace tube, and the thermo-element drawn through the capillary, which terminated in the third arms of T-pieces before and after the furnace. The wires of the thermo-element were soldered to fine copper wires 500 mm. in length and the junctions were kept in ice. These copper wires were connected by mercury contacts with stout copper wires which passed to the galvanometer some metres distant. The resistance in the circuit exclusive of the galvanometer amounted to 2·75 ohms, which denotes an error of 0·9 per cent. in the temperature. This was, however, disregarded, as the fluctuations in the temperature of the junction were more considerable.

Protection of the thermo-couple

The temperature readings at different points in the tube were taken by pushing the wires of the thermo-element to and fro in the capillary, the distances of the couple from the centre of the furnace being observed by means of scratches on the wires. After a few readings the initial point was again checked. It was always found to have remained constant if measurements had not been made too rapidly after the commencement of heating. The temperature altered as soon as the passage of vapour began, and had to be regulated by the current. During the passage of vapour, provided that the current was not varied, the temperature within the tube only fluctuated in consequence of changes in the rate of gasification, of which it therefore gave a very ready indication.

Precautions to test constancy of the temperature

The furnace was blown out with acetylene, and the silver solution and sulphuric acid washing-flasks were removed from the apparatus. The gas-collecting globe was filled with a solution of common salt, saturated with carbonic acid. The acetylene used was made from calcium carbide, was free from air, and contained 97 per cent. of pure acetylene. It passed through

Method of performing the experiment

washing-flasks containing a solution of caustic soda and calcium chloride before it reached the furnace. The temperature at the hottest part of the tube ranged from 638° to 645° C. during the experiment. In 4 hours 49 minutes 15·24 litres of gas were passed through, and 10·83 litres were obtained from it, both volumes being measured over brine under like conditions. The gas collected contained 91·8 per cent. of acetylene, 1·3 per cent. of ethylene, *i.e.* absorbed by bromine but not by silver solution, and 1·7 per cent. of combustible constituents not absorbed by bromine. The remainder of the gas was carbonic acid from the confining liquid. The formation of gaseous olefines and paraffins and the splitting off of hydrogen were therefore inconsiderable, but there was a marked production of solid and liquid products. The tube increased in weight by 0·50 gr., the tar collector by 2·304 grs., and the paraffin oil flasks by 0·9 gr. The actual carbon amounted to very little. The tar began to boil at 80° C., and about 40 per cent. distilled under 84° C. Then the residue distilled fairly uniformly up to 305°, when a small quantity of carbonaceous residuum was left. Formation of naphthalene was not detected.

Results obtained

Results at a higher temperature

An experiment carried out similarly at 790° C. was brought to a conclusion in half an hour through a thick deposit of carbon in the tube. The tar was extremely thick and viscous, but benzene was detected by nitration, and there was an odour of naphthalene. The gas contained in addition to 25 per cent. of acetylene only hydrogen and quite insignificant quantities of methane and olefines."

Discrepancies between the results of Lewes and Haber

The apparent discrepancy in the results obtained by Lewes and Haber is manifestly due to the temperature employed; as whilst Lewes passed the acetylene through 25 mm. of heated tube at 1,000° C., Haber only employed a temperature at which acetylene

undergoes polymerisation and not decomposition. In Lewes' experiment it was the nascent hydrogen liberated by the decomposition of the acetylene which, combining with more acetylene, formed the unsaturated hydrocarbons found in the residual gas.

The luminous decomposition of Acetylene

In 1895, Lewes[1] made the interesting observation that the decomposition of acetylene by heat liberates the carbon in an incandescent condition owing to the endothermic heat of the compound being confined at the moment of decomposition to the products. Commenting on the flash of bright light seen when acetylene is detonated by mercuric fulminate as in Berthelot's experiment, he says: "Although the instantaneous liberation of heat on the decomposition of the gas by detonation appears to confine the temperature to the products of its decomposition, it was to be expected that on being decomposed by heat, and probably therefore at a slower rate, the increase in temperature should be detected.

Light emitted when Acetylene is detonated

To prove this, pure acetylene was passed through a platinum tube 2 mm. in diameter and 40 cm. long, in which a Le Chatelier couple was arranged. A steady flow of acetylene was allowed to pass through the tube, and was led into water at the other end. The tube was slowly and carefully heated for about 100 mm. of its length, and as the temperature reached 700° C. white vapours began to flow from the tube, and these, as the temperature rose, increased in quantity. The source of heat had been so regulated that the temperature had risen about 10° per minute; but almost immediately 800° C. was passed the galvanometer registered a sudden leap up in temperature to about 1,000° C., whilst finely divided carbon poured from the tube. This seemed to indicate that 800° C. was about the temperature at which the pure acetylene broke up into its constituents, and an experiment

Sudden evolution of heat on decomposing Acetylene

[1] *Proc. Roy. Soc.*, 57, 455.

was now made to see if this developed incandescence in the liberated carbon.

A small glass combustion tube was well supported, and heated to the highest temperature attainable with one of Fletcher's big blowpipes, whilst pure acetylene was flowing slowly through it, the heating not being commenced until the tube was filled with the pure gas, all air being thoroughly rinsed out. As the temperature reached the softening point of the glass, the acetylene apparently burst into a lurid flame at the point where it entered the zone of heat, and clouds of carbon swept forward through the tube; but although the carbon particles had to traverse 25 mm. or more of tube more highly heated than the point of entering the hot zone, it was only at this latter point that the luminosity was developed, proving beyond doubt that it was the heat evolved by the decomposition, and not the external heating, which caused the carbon particles to emit light."

The Carbon separates from decomposing Acetylene in an incandescent condition

Haber failed to obtain this phenomenon except when small quantities of oxygen were present in the original gas, but this was probably because the rate of flow in the tube was too slow. Under these conditions the acetylene polymerises into benzene and other compounds as it approaches the heated zone, and the vapours so dilute the acetylene that no luminous decomposition takes place, the temperature used being insufficient. The acetylene employed in Lewes' experiments was carefully freed from oxygen.

Dilution with other gases retards the luminous decomposition and necessitates a higher temperature

Lewes [1] has shown that the temperature necessary to bring about the luminous decomposition of acetylene increases with the degree of dilution of the acetylene; and in order to do this a tube made of specially infusible glass 4 mm. in diameter was taken, and the Le Chatelier thermo-couple was fitted into it in the same way as before used with the platinum tube, and

[1] *Proc. Roy. Soc.*, 55, 90.

all air having been rinsed out by a current of the mixture to be experimented with, the gas was allowed to pass at a steady rate of flow through the tube, the point at which the thermo-couple was situated being steadily heated by the Fletcher blowpipe, whilst the temperature recorded on the scale was noted the moment that the incandescent liberation of carbon commenced.

Temperatures needed to cause decomposition of diluted Acetylene

Percentage composition of gas.		Temperature necessary to cause deposition of carbon with luminosity.
Acetylene.	Hydrogen.	
100	0	780° C
90	10	896
80	20	1,000

It was found impossible to obtain a glass tube which would stand temperatures higher than this; but on plotting out the points so obtained, and which give a fairly straight line, it is seen that even if the increase in temperature only continues for increased dilution in the same ratio as shown in the experimental determinations, which is extremely unlikely, the reason of the destruction of luminosity in highly diluted hydrocarbon gases is at once explained, as an increase of each 10 per cent. in the dilution would necessitate an increase of 100° C. in the temperature of the flame, and with 90 per cent. dilution a temperature of over 1,700° C. would be required to bring about decomposition.

The action of heat on Acetylene

The action of heat upon acetylene is probably far more complex than any of these experiments indicate, and the products will vary with every change in the temperature: the first action is undoubtedly condensation to benzene, and, with a careful regulation of temperature, it is conceivable that the action might possibly be limited to this; but with a slight increase in the heat further changes, due to the shedding of hydrogen, continue until, as noticed by Berthelot,

naphthalene and tar are formed just below the point of decomposition.

Secondary actions taking place

Whilst these changes are progressing, secondary actions of an additive character are also taking place, the nascent hydrogen from one molecule attaching itself to others, and thus building up ethylene, which in turn breaks down again to acetylene and methane, and so by actions of both synthetical and analytical character are formed the great numbers of compounds generated by acetylene between 400° and 780° C., above which temperature it is decomposed into its constituent elements.

Acetylene always present in the interior of luminous hydrocarbon flames

Experiments made by withdrawing the gases from various parts of luminous flames show that no matter what is the initial character of the hydrocarbon present, acetylene is always produced before luminosity makes its appearance, and moreover that the illuminating power of the flame follows the ratio of acetylene so produced; and this fact, taken in conjunction with the observation that when acetylene, free from air, is allowed to flow through a Jena glass tube heated up to a temperature of 780° C., it is decomposed with luminosity, whilst the carbon set free in flowing forward through the zone of heat is perfectly non-luminous, formed the basis of what is now known as the acetylene theory of luminosity.

The acetylene theory of luminosity

Stated in its simplest form, this theory is as follows:—In the same way that the decomposition of the acetylene in flowing through a heated tube endows the carbon particles with a luminosity which the heat of the tube alone is unable to impart, so does the decomposition of the acetylene generated in a hydrocarbon flame increase the light-yielding power of the carbon particles liberated by its decomposition over what might have been the light emitted had they only been heated to the temperature of the flame itself.

There are conditions under which acetylene can be burnt without the development of light. If acetylene be diluted with about 92 per cent. of hydrogen or carbon monoxide, the molecules are burnt up without decomposition, and there being no solid matter in the flame to heat to incandescence, the flame remains non-luminous. This is due to the acetylene requiring a higher temperature to decompose it when it is diluted than when it is pure, and the greater the dilution the higher the temperature needed.

Acetylene may be present in non-luminous flames

If burning alcohol, which in the open air gives a faintly luminous flame, be placed under a bell-jar, the temperature of the flame is lowered by some of the products of combustion being checked in their escape, and the flame becomes absolutely non-luminous; if now oxygen be supplied to the flame its temperature becomes greatly increased, and not only does the flame become highly luminous, but freely deposits carbon on a cold surface held within it, whilst gas withdrawn from the interior of the flame under each condition is found to contain acetylene in abundance.

The alcohol flame

Presence of Acetylene in the alcohol flame

Another very striking example of the same kind is to be found in cyanogen, a gas which has always been noted for the beauty of the rose-pink flame with which it burns. Although cyanogen contains the same amount of carbon as acetylene, and is even more endothermic, no one until lately had ever thought of the possibility of its burning with a luminous flame, this being due to the fact that the temperature necessary to break up the molecule was so far above the heat of the flame that the cyanogen molecule burnt as a whole, and there being no deposition of carbon no luminosity would result.

The flame of cyanogen

If, however, the cyanogen flame be surrounded with pure oxygen instead of air, a faint luminosity appears in the flame owing to the increase of temperature; whilst if the flame be surrounded by

Cyanogen more luminous than acetylene itself

nitrogen dioxide, another endothermic compound, the temperature is so increased that the flame becomes more intense in its illuminating power than the acetylene flame itself, and yields a dense deposit of carbon and para-cyanogen to any cold surface held within it.

The acetylene theory of luminosity will be found more fully discussed in the chapter devoted to the combustion of acetylene for the development of light.

Temperature of decomposition

Lewes gives the temperature of decomposition of acetylene as 780° C., whilst Haber places it between 770° and 790° C. Frank, however, gives it as above 1,000°, but upon what evidence is not clear.

Le Chatelier's researches on the products of combustion of Acetylene

Davy,[1] in 1836, in his original paper, pointed out that acetylene burns in air "with a bright flame, denser and of greater splendour that even olefiant gas (ethylene). If the supply of air is limited, the combustion of the gas is accompanied by a copious deposition of carbon." He also found that one volume of acetylene required $2\frac{1}{2}$ volumes of oxygen, or approximately $12\frac{1}{2}$ of air, for its complete combustion, and yielded 2 volumes of carbon dioxide and one of water vapour. In 1895, Le Chatelier made an interesting research on the combustion of mixtures of air and acetylene and found[2] that the combustion of mixtures of acetylene and air containing less than 7·74 per cent. of the former, burn completely to carbonic acid and water with a yellowish flame of low illuminating power. Between 7·74 and 13·37 per cent. the flame is pale blue with a feeble yellowish aureole, and hydrogen and carbon monoxide are amongst the products of combustion, the relative proportions of these gases being represented by the same formula of equilibrium as in the case of other combustible gases. With more than 13·37 per cent. of acetylene the

[1] *Brit. Assoc. Report*, 1836, 62.
[2] *Compt. Rend.*, 121, 1144.

reactions are incomplete, and free carbon and unburnt acetylene are present in the gases from the flame, as well as hydrogen and carbon monoxide, the flame being red and smoky.

Limits of combustion in mixtures of air or Oxygen and Acetylene

	In oxygen.	In air.	
Lower limit of combustibility .	2·8	2·8	per cent. acetylene.
Upper " " " .	93·0	65·0	" "

In tubes these limits decrease as the diameter decreases. The flame of a mixture of air and acetylene cannot travel along tubes the diameter of which is less than 0·5 mm., only in tubes 1 mm. in diameter can the flame of the most inflammable mixtures pass.

Influence of the diameter of tubes on the explosive limit

Diameter of tubes. mm.	Limit. Lower per cent.	Upper per cent.
0·5		
0·8	7·7	10
2	5	15
4	4·5	25
6	4	40
20	3·5	55
30	3·1	62
40	2·9	64

Velocity of propagation of the flame

In a tube 40 mm. in diameter the velocity of the flame is 0·1 m. per second, with 2·9 per cent. of acetylene, but increases rapidly with the percentage of acetylene until the latter reaches 8 per cent., when the velocity is 5 mm. per second, and afterwards it increases slowly to a maximum of 6 mm. per second with 9 to 10 per cent. of acetylene, whilst beyond this limit it decreases rapidly. The temperature of ignition is only 480° C., and hence explosive mixtures of acetylene can be ignited in glass tubes heated with a spirit lamp. The calculated temperature of combustion with 7·74 per cent. of acetylene is 2,420° C.

Temperature of ignition of mixtures of air and Acetylene

$$t = 2{,}420°;$$

$$C_2H_2 + 2{\cdot}5O_2 + 9{\cdot}4N_2 = 2CO_2 + H_2O + 9{\cdot}4N_2;$$

Heat of combustion of various

mixtures of Acetylene and air

for 12·2 per cent. of acetylene, when the conditions of equilibrium are—

$$C_2H_2 + 1{\cdot}5O_2 + 5{\cdot}65N_2 + \tfrac{4}{6}(2CO + H_2O)\ \tfrac{2}{6}(CO_2 + H_2) + 5{\cdot}65N_2. \quad t = 2{,}260°;$$

Heat of combustion of Acetylene and oxygen

for 17·37 per cent. of acetylene the temperature of combustion t = 2,100°; when burnt with its own volume of oxygen, the temperature of the flame should be 4,000°, which is 1,000° higher than the oxy-hydrogen flame.

The heat of combustion has been determined by Thomsen [1] as being 310,500 calories; and also by Berthelot,[2] who found it to be 321,000 calories.

Development of power on explosion

The fact that acetylene is combustible and highly endothermic, whilst the igniting point is lower than that of any other inflammable gas, would at once lead one to expect that the explosion of mixtures of acetylene and air would develop greater power than with ordinary combustible gases, and in 1894 L. Meyer [3] published a warning note on this subject, in which he

Force of explosion of mixtures of Acetylene and Oxygen

recounts that whilst exploding a mixture of acetylene and oxygen as a lecture experiment, the small glass cylinder containing the gases and surrounded with a duster was blown to pieces, even the solid foot being smashed to atoms by the violence of the explosion.

He calculated that the temperature of the combustion of acetylene was 11,180°, whilst that of ethylene would be 9,160°. These temperatures, however, are probably never reached on account of dissociation.

As early as 1874 E. v. Meyer,[4] whilst making experiments on incomplete combustion, had noticed the violence with which mixtures of acetylene and oxygen explode, and attributed it to the endothermicity of the compound; and he also found that whilst a mixture of 1 volume of acetylene to 0·2286 of oxygen is

[1] *Thermochem. Unters.*, 4, 74. [2] *Ann. Chim. Phys.*, 5, 9, 165.
[3] *Berl. Ber.*, 27, 2764. [4] *Journ. f. Prakt. Chem.*, 10, 233, 341.

inflammable, when the oxygen is reduced to 0·184 of a volume the mixture ceases to inflame.

Clowes' experiments on the explosive limits of mixtures of combustible gases with air

The most valuable work on the limiting proportions of mixtures of acetylene and air which give explosion was done by Clowes.[1] The experiments were conducted as follows:

The mixtures were made in a glass cylinder of known capacity 75 mm. in diameter, which was closed at one end. A volume of water equal to that of the combustible gas to be introduced was poured into the jar, and a light xylonite ball, whose volume had been allowed for in taking the capacity of the cylinder, was dropped in.

Method of making the determinations

The jar was then inverted with its open mouth in a pan of water, and the remainder of the water was replaced by the combustible gas. The mouth of the cylinder was then closed by a glass plate. After the closed cylinder had been removed from the water, the air and gas were thoroughly mingled by causing the ball to run up and down inside some twenty times.

The cylinder was then removed into a dark room, and a small Bunsen atmospheric gas flame was brought to its mouth.

If a sheet of flame travelled quickly through the whole length of the cylinder, the mixture was considered to be combustible independently of the external atmosphere. Such a mixture, although it burst silently in the small mass contained in the cylinder, would undoubtedly produce explosive effects if it were kindled in larger quantity.

If the mixture refused to kindle in contact with the flame, or if it simply burnt slowly as the external air reached it, it was considered to be non-explosive at ordinary atmospheric pressure.

Influence of ignition from below or from above

It was found that the mixtures were more readily kindled upward by a flame introduced at the bottom

[1] *Brit. Assoc. Reports*, 1896.

than downward by a flame introduced at the top. Accordingly the composition of the limiting explosive mixtures varied according as the firing was upward or downward.

The experiments were carried out with several different combustible gases, and with coal gas. The limiting explosive mixtures varied in their proportion of gas to air when different gases were employed.

In order to measure accurately small volumes of inflammable gas in making the mixtures, the gas was diluted with nine times its volume of air. In this way a tenfold volume could be dealt with. Allowance was made for the air thus introduced with the gas, in calculating the composition of the mixture to be experimented with.

The results obtained by repeated experiments made with the same gas were concordant. In every case the next percentage of gas, below or above as the case might be, failed to fire back.

Explosibility of mixtures of air and Acetylene

It was found that air must contain at least 3 per cent. of acetylene before it can be kindled with a flame, and the mixture caused to burn throughout. As the proportion of acetylene is increased the explosive character is augmented. When 22 per cent. of acetylene is present, carbon begins to separate during the burning. The amount of carbon which separates increases until the explosive character of the mixture disappears. This point is reached when 82 per cent. of acetylene is present in the air.

The limiting percentages in air which are explosible are, accordingly, as follows, and may be compared with those already determined for other combustible gases.

Comparison of the explosive limits of mixtures of combustible gases with air

Acetylene	3 to 82
Hydrogen	5 to 72
Carbon monoxide	13 to 75
Etheylene	4 to 22
Methane	5 to 13

It will be seen that acetylene gives a wider range of explosive proportions than any other of these gases does. Probably this is due to its endothermic character, which leads to the gas being able to generate heat by its own decomposition. Heat thus generated would undoubtedly aid in causing explosion, and would thus extend the limits of explosive mixtures.

Some experiments on the same subject are recorded by Le Chatelier and Boudouard,[1] who give the lower limit of inflammability as 2·8 per cent. of acetylene.

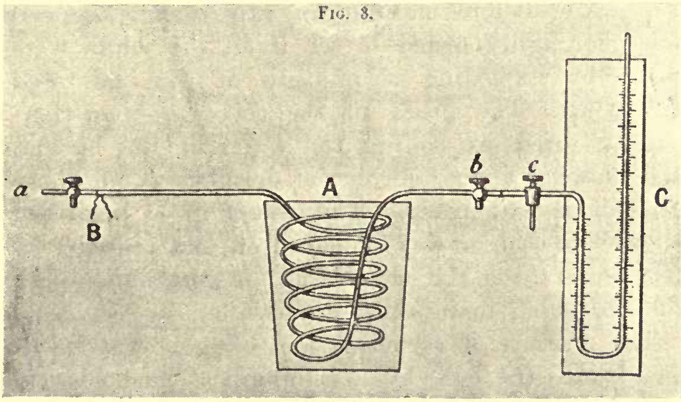


Fig. 22.

The products formed when Acetylene is exploded with less than its own volume of Oxygen

When acetylene is exploded with $2\frac{1}{2}$ times its own volume of oxygen, carbon dioxide and water vapour are produced, and Bone and Cain,[2] have studied the reactions taking place when acetylene is exploded with less than its own volume of oxygen. The experiments were carried out as follows:

Apparatus employed

As mixtures of acetylene and oxygen explode with great violence, it was necessary to carry out the operation in a leaden coil. The coil A (Fig. 22), 5 metres long and of an internal diameter of 13 mm.

[1] *Compt. Rend.*, 126, 1510.
[2] *Journ. Chem. Soc.*, 71, 26.

capacity about 700 cc., was immersed in a bucket of cold water, a stout glass firing-piece B being attached to the coil, by means of Faraday cement. Each end of the coil was opened by strong steel taps *a b* and communication was made through *b* and a glass tail tap *c* with a mercury manometer C; the latter served to indicate, as will afterwards be shown, the pressure in the coil after an explosion. By means of a tail tap *c* a direct connection could be made with the outside atmosphere instead of with the manometer, so that the products of explosion could be readily drawn off for analysis. Before making an experiment, the coil was thoroughly tested to see if all the joints were tight by exploding a mixture of coal gas and air in it. The inside of the coil was then thoroughly dried by boiling the water in the bucket, and blowing a good current of dried air through the coil for several hours. The water in A was then allowed to cool, or was syphoned off and replaced by cold water from the mains, the air current through the coil being maintained meanwhile.

Precautions taken in preparing the apparatus

The introduction of the gaseous mixture

The mixture of acetylene and oxygen was introduced into the coil by attaching the gasholder to the end *a* and raising the mercury reservoir; then, on opening the taps *b* and *c*, the air was expelled from the coil. After about a litre of the mixture had been passed into the coil, the exit gases from *c* were found to be highly explosive; but another half-litre of gas was sent through the coil in order that there might be no doubt as to its being filled with a gaseous mixture of the same composition as that originally made in the gasholder; the tap *a* was then closed and a few moments later the tap *b*. Thus the coil was filled with gas at the ordinary atmospheric pressure. The tap *c* was then turned so as to bring the coil in connection with the manometer, and the mixture was fired by an electric spark at B. If the various joints

had successfully resisted the shock of the explosion, the coil and its contents were allowed to stand for a quarter of an hour in order that they might cool down to the temperature of the surrounding water, and then by opening the tap *b* connection with the manometer c was made, and the pressure of the gases in the coil read off. In every case a considerable increase in pressure was observed. Finally, samples of the products were drawn off through *c* and collected in tubes over mercury: these samples were subsequently carefully analysed. The rest of the products were displaced by a current of air, and sent through an ammoniacal solution of silver chloride. In every case a precipitate of silver acetylene, identified by the usual method was obtained, showing that the products of explosion contained free acetylene.

Methods of determining pressures and results

The results of their experiments are briefly stated as :

Results obtained from the experiments

1. When acetylene is exploded with less than its own volume of oxygen, carbon monoxide and hydrogen are finally obtained, owing to the partial combustion of the acetylene in accordance with the equation—

Products formed

$$C_2H_2 + O_2 = 2CO + H_2,$$

the cooled products of explosion in the coil being under considerable pressure.

2. The excess of acetylene is for the greater part resolved into its elements by the shock of the explosion wave. A small quantity of acetylene—as much as 1 per cent. in some cases—is, however, found in the products of explosion. This may be due to acetylene which has escaped decomposition altogether, or possibly to a recombination of hydrogen and carbon in the rear of the explosion wave. The presence of any other unsaturated hydrocarbon in the products of explosion has not been detected.

Effect of the explosion on excess of Acetylene

3. Methane does not appear to be formed when

Absence of Methane from the products of decomposition

acetylene is exploded with less than its own volume of oxygen, at any rate not in any appreciable amount. This point has been very carefully investigated, and although from some of the earlier experiments the presence of a small quantity of methane—some 0·5 per cent.—in the products of explosion was suspected, a more rigid examination left no doubt that methane was entirely absent.

This is particularly interesting, seeing that when ethylene is exploded with less than its own volume of oxygen, methane is produced, in certain cases to the extent of 6 per cent. of the whole products. The difference in the two cases is probably due to the fact that acetylene is readily resolved into its elements by shock, whilst in the case of ethylene the excess of hydrocarbon which escapes combustion is subjected to a "roasting" process, and thereby decomposed into carbon and methane.

Traces of Carbon Dioxide formed

4. Small amounts of a gas absorbable by solid potassic hydroxide were invariably found in the products of explosion. This was in part, if not altogether, due to the presence of carbon dioxide; for when the products of explosion were aspirated through a clear solution of baryta, a white precipitate of barium carbonate was formed.

Deposition of Carbon

5. Carbon was deposited. This was shown by firing a small volume of each mixture in a short eudiometer made of very stout glass. In the case of mixtures containing acetylene made with less than three-quarters of its own volume of oxygen, a thick deposit of carbon formed, but where mixtures contained a larger proportion of oxygen, much less carbon separated.

Whilst it follows that the main reaction, occurring when acetylene is exploded with less than its own volume of oxygen may be expressed by an equation such as one of the following:—

$$C_2H_2 + O_2 = 2CO + H_2$$
$$2C_2H_2 + O_2 = 2CO + 2H_2 + 2C$$
$$3C_2H_2 + O_2 = 2CO + 3H_2 + 4C$$

Probable action taking place

it must be admitted that some steam is also produced: this is evident from the fact that the ratio of the hydrogen to the carbon monoxide in the products is always less than the above equations require. Moreover it would be very difficult to account for the presence of carbon dioxide in the products were no steam produced.

Some remarkable results, due probably to the combined action of explosion with air, and detonation of the excess of acetylene have been observed by Gerdes.[1]

Gerdes' experiments on the pressures produced on exploding mixtures of Acetylene and air

Working with 90 litres of the various mixtures in an explosion cylinder, and measuring the pressures by means of a manometer and indicator, the following results were obtained:—

Pressures given by exploding mixtures of acetylene and air.

Percentage of Acetylene	Atmospheres Pressure	Percentage of Acetylene	Atmospheres Pressure
2·5	0·05	11·1	11·1
3·7	3·7	12·5	10·6
4·7	4·9	16·6	7·2
5·5	5·2	20·0	16·0
6·6	6·8	25·0	16·9
7·7	8·2	33·0	18·4
8·3	8·6	50·0	20·3
9·1	9·7	66·0	10·0
10·0	11·1	80·0	6·3

These results show that the maximum of explosive force is obtained with a mixture of equal volumes.

Maximum of explosive force

The maximum of pressure should occur when completed combustion yields the greatest heat effect, and the acetylene is burned to carbon dioxide and water vapour, and this mixture explodes with the greatest noise.

[1] *Zeitsch. Calc. Ac.*, 2, 260.

Gerdes explains this unexpected result by the assumption that the carbon is gaseous at the moment of liberation, but this theory is hardly tenable. If a mixture of equal volumes of acetylene and air be ignited in an open cylinder 500 mm. high, a lurid disc of flame runs down the cylinder and a vast cloud of carbon is given off, but no sign of anything approaching explosion occurs. If, however, this be done in a closed vessel, the very slowness of the combustion brings about the explosion, as the combustion of the portion of the mixture first ignited creates a pressure under which the remainder detonates at the temperature of combustion, and gives the high pressure noticed in these experiments.

Explanations of this phenomonon

In experiments made by Polis, it was found extremely difficult to ignite such a mixture of air and acetylene in a tube by means of an electric spark; but if a flask be employed so that a considerable volume of the mixture be present, the spark at once causes a violent explosion, the finely divided particles into which the glass is blown being an ample proof of the explosive force having been of an extremely sharp character.

The fact that a mixture of one volume of air and one volume of acetylene burns extremely slowly in an open cylinder, and also the fact that it is difficult to ignite by a spark the mixture in small proportions, are no argument against the explosibility of the mixture; as, if one takes a mixture of carbon disulphide and nitric oxide in a short cylinder, it burns with simply a bright flash of light, which is noted for its richness in actinic rays, whereas, if a very long narrow cylinder be employed, it burns downs to a certain point and then detonates, blowing the cylinder to pieces; such phenomena being entirely due to the increase in rapidity of combustion, which finally terminates in an explosive wave.

Formation of an explosive wave

The whole question of the explosive properties of

acetylene is well summarised in a communication made by M. Berthelot to the International Acetylene Congress, held at Buda-Pesth in May, 1899, which is as follows:—

Berthelot gives a summary of the explosive question

"The remarkable lighting properties, which have given such impetus to the Acetylene Industry in Europe and America, are bound up in closest union with the explosive properties of the gas, both depending on the exceptional heat developed in combustion by reason of its endothermic character, the luminosity of the flame increasing rapidly with the rise of temperature. The explosive properties of gases used for lighting purposes are of two kinds—the one common to all combustible gases mixed with air, and the other peculiar to endothermic gases such as acetylene.

The illuminating properties and explosibility of Acetylene both due to its endothermic properties

The properties common to all combustible gases mixed with air do not differ much in acetylene and coal gas except for slight variations in the limits of the relative proportions and the heat at which ignition takes place, the presence of actylene tending generally to lower these limits. The precautions to be taken, however, are, on the whole, the same; they have been the object of numerous and thorough researches, on which I have no need now to touch.

Explosive mixtures of Acetylene and air

Acetylene is the only one amongst the usual lighting gases likely to explode by itself and without oxygen, and its properties in this connection have been the objects of my researches since 1865. Indeed, it was at this period that I discovered that acetylene was formed from its elements with absorption of heat, that is to say, that it was endothermic and decomposable with evolution of heat. I have since measured the heat given off in its decomposition, and found it about equal to the heat given off by the combustion of an equal volume of hydrogen. From this it follows that acetylene might be explosive by itself, a fact which I verified in 1882 by detonating this gas by

Berthelot's account of his great discoveries

means of a cap of fulminate of mercury. This property is apparent in cyanogen, whilst methane and the analogous carbides—notably those of petroleum—are formed with the generation of heat, and therefore will not detonate by themselves. Owing to this circumstance, the temperature of their combustion is lower, and their lighting power less considerable.

Illuminating power of Acetylene

The advantage of acetylene in this respect is very marked, its lighting power being six or seven times as great as that of coal gas, and as it can be economically prepared on the spot, every one is making his own gas without special systems of pipes; these conditions go far to extend its general use.

Care must be taken, however, to guard against its explosibity, and it is in this study that I have been occupied with M. Vielle for many years from a purely scientific point of view.

The influence of pressure on the explosibility of pure Acetylene

He first investigated the influence of pressure, a research made necessary by the use of liquid acetylene. The use of this is particularly simple, as it only calls for the employment of strong receivers capable of resisting great pressure, such as are manufactured on a large scale at the present day. Acetylene lighting thus becomes as simple as the use of oil lamps.

The spread of the explosive wave in Acetylene

It has already been stated that the explosive decomposition of acetylene brought about at any one point by a spark or an ignited body does not spread beyond the region submitted to the direct action of the heat. It is quite the reverse when the gas is condensed and under a pressure of more than two atmospheres. The reaction then spreads, and gives rise to violent explosion.

The effect of shock in causing explosion

Shock, pure and simple, or even crushing, of the receiver, does not give rise to explosion, provided the pressure does not exceed ten atmospheres, and that no sparks are produced in the crushing. But the shock produced by a cap of fulminate will give an explosion.

An explosion can also be brought about in compressed acetylene if water in excess be dropped on to the calcium carbide in such a way as to raise any portion of the mass to incandescence. The effect of overheating during generation

The same risk exists when the gas is compressed too hastily in a reservoir, or even when the gas previously compressed escapes rapidly from the receiver to be again compressed further on at the mouth of a holder, in fact, every time acetylene is submitted to sudden heat by means of too hasty compression. The effect of too sudden compression

These various observations define the dangers run in the use of liquid acetylene, and at the same time suggest the precautions which must be taken to regulate its employment and prevent the risk, precautions simple enough to be observed. Attempts have been made to diminish the risks by resorting to the use of solvents, the presence of which tends to stay the explosive properties of the acetylene dissolved in them, whilst permitting the gas given off to resume its previous conditions. The retarding influence of solvents

Amongst these solvents is acetone, which dissolves 20 to 25 litres of acetylene for every kilogramme of absolute pressure, which would give, for example, 40 per cent. lbs of acetone under a pressure of 13 kilogrammes. The explosive liability of such a mixture is much diminished, as no explosion can take place in the heart of the liquid itself, either by simple ignition, or under the action of a cap, unless the pressure is considerably over 10 kilogrammes more than the ordinary temperature. The explosive properties of solutions of Acetylene in acetone

It is different with the gas arising from the solution, for the acetylene having become almost pure again recovers its normal explosive properties.

In the case of the explosion taking place in the liquid itself, the solvent, *i.e.* the acetone, is at the same time destroyed, this destruction absorbing part The effect of explosion on the solvent

of the heat given off by the acetylene and tending to diminish the effects of the explosion.

Instead of burning pure acetylene in a gaseous state from a receiver containing it in a liquid condition or dissolved in a suitable solvent, we have tried latterly to burn acetylene mixed with a non-explosive gas, capable of lessening the condensation of the explosive gas as well as the heat developed by its decomposition.

The effect of gaseous diluents in retarding explosion

These results become more marked if we employ as the added body an exothermic compound capable of being destroyed by the heat evolved by the decomposition of the acetylene. This compound may itself be endued with luminosity which would be increased by the addition of the acetylene. We have experimented with mixtures of this kind, the first consisting of acetylene and hydrogen, and the second acetylene and ordinary lighting gas. We have noted that the aptitude of acetylene to spread decomposition excited at any one point varies rapidly with the pressure, and that there exists for each mixture a curve of pressure, a zone below which the probability of propagation becomes almost nil, and a knowledge of which determines the degree of safety in industrial enterprise.

The safety limits of pressure in mixtures of Acetylene with other gases

This limit, for example, has been found to be at about 4 kilogrammes from the initial pressure in a mixture of equal volumes of acetylene and hydrogen, and at about 10 kilogrammes in a mixture of 3 volumes of hydrogen to 1 of acetylene.

For ordinary lighting gas the limits are still higher, being about 7 kilogrammes in equal volumes, and 40 kilogrammes for a mixture containing only one-fourth of acetylene. The risk is thus diminished by the presence of a coal gas, a gas rich in methane, a compound decomposable by absorption of heat. This influence conforms to the theory advanced above.

At the same time, the gas which in use diminishes

the heat developed in the decomposition of the acetylene, as well as in combustion, decreases thus to a certain degree the illuminating power. It is between these two classes of phenomena that we must steer in practice, seeking at the same time those conditions least dangerous in use, and those most favourable to the development of the light."

The ends to be attained in practice

Bone and Wilson[1] have made some experiments on the effect of light on acetylene. The gas was prepared from copper-acetylene by the action of hydrochloric acid, and was exposed during June and July to the action of direct sunlight. A brownish deposit formed, and in fourteen days the surface of the glass tubes enclosing the gas was completely covered. The composition of the deposit was not ascertained, and where the tube was screened from light no deposition took place. The action also seemed to cease when the sides of the tube were sufficiently clouded to cut off the direct rays.

The effect of light on Acetylene

It should be noted that Roemer,[2] in 1886, found that acetylene prepared from copper-acetylene by the action of hydrochloric acid yielded a dark deposit on the sides of the glass gasholder in which it was standing, and no change of volume was noted. The deposition, however, seemed to be independent of the action of light, and may be due to one of the polyacetylenes discovered by Baeyer.

Roemer notices a deposit from Acetylene prepared by the action of Hydrochloric Acid on Copper-Acetylene

The action of the induction spark upon acetylene was tried by Berthelot,[3] who found that under its influence the gas partly decomposed with liberation of carbon, whilst some polymerised to liquid products, and part also condensed to polyacetylenes.

The action of the induction spark on Acetylene

The action of oxidising agents upon acetylene was also first tried by Berthelot,[4] who investigated the action of an alkaline solution of potassium permanganate

The action of oxidising agents upon Acetylene

[1] *Proc. Chem. Soc.*, 14, 155. [2] *Lieb. Ann.*, 233, 182.
[3] *Compt. Rend.*, 93, 613. [4] *Ibid.*, 64, 34.

upon the gas, and found that, after shaking with the solution and well cooling, potassium formate and oxalate were formed and carbon dioxide was produced, but later, 1870,[1] he tried the action of chromic acid, and found that, according to the concentration of the solution used, he obtained either formic acid and carbon dioxide, or acetic acid.

In 1882 Mailfert[2] tried the effect of ozone upon acetylene, and found that it converted it into formic acid and carbon dioxide.

Action of Palladium on mixtures of air and Acetylene

F. Phillips,[3] in a paper on the oxidation of hydrogen and hydrocarbons, finds that in the presence of palladianised asbestos at temperatures above 339° C. 31 per cent. of the acetylene mixed with air is completely oxidised to carbon dioxide and water, and that under these conditions acetylene is more stable than hydrocarbons of the ethylene series. He also finds that the oxidation of the carbon and hydrogen takes place simultaneously, forming water and carbon dioxide, whilst if there is not sufficient oxygen, carbon monoxide may also be produced.

In 1896 Campbell[4] passed pure acetylene over palladianised copper oxide, and found that even at 225° to 230° C. water begins to form, but no carbon dioxide, and even up to 400° C. carbon was deposited in the combustion tube, and the proportion of water produced was always in excess of the carbon dioxide.

Action of Peroxide of Hydrogen on Acetylene under pressure

Bergmann,[5] in 1897, stated that if acetylene under 5 atmospheres pressure be heated with hydrogen peroxide to 150° C., water and graphite are produced.

The catalytic action of

It was De Wilde,[6] in 1866, who first pointed out that under the catalytic action of platinum black, acetylene and hydrogen would unite to form ethane,

[1] *Compt. Rend.*, 67, 417. [2] *Ibid.*, 94, 860.
[3] *Zeitsch. f. Anorg. Chem.*, 6, 212.
[4] *Amer. Chem. Journ.*, 17, 681.
[5] *Journ. f. Gasbel.*, 41, 689. [6] *Bull. Soc. Chim.*, 2, 5, 175.

$$C_2H_2 + 2H_2 = C_2H_6,$$

Platinum Black on Acetylene and Hydrogen

whilst later[1] he repeats this statement, and also concludes that under certain conditions ethylene also might be obtained,

$$C_2H_2 + H_2 = C_2H_4.$$

The tendency of nascent hydrogen to attach itself to the molecule of acetylene with formation of ethylene was demonstrated by Berthelot in 1862,[2] when he acted on copper-acetylene by nascent hydrogen, produced by the action of ammonia solution on finely divided zinc, and produced ethylene.

Acetylene Hydrate

When cold water is saturated with acetylene under pressure, a well-defined and crystalline hydrate, C_2H_2 $6H_2O$, is formed, and being heavier than water, sinks to the bottom of the solution.

It was Villard[3] who in 1897 discovered this compound, and investigated its properties.

Conditions necessary for formation and preservation of Acetylene Hydrate

He found that at atmospheric pressure it required a temperature of $-40°$ C. to prevent any decomposition taking place, and that the compound dissociated under the following conditions of temperature and pressure into water and acetylene once more.

Temperature.	Pressure.
0° C.	5·7 atmospheres.
4·6	9·4 ,,
7·0	12·0 ,,
9·6	16·4 ,,
15·0	33·0 ,,

Villard uses the formation and dissociation of this hydrate as a method of obtaining pure acetylene.

In 1894 Deprez[4] found that a considerable volume of gaseous acetylene was absorbed by freshly burnt charcoal, and that on heating the mass in water in a closed tube to 325°, and keeping it at that tempera-

[1] *Berl. Ber.*, 7, 352.
[2] *Compt. Rend.*, 54, 315.
[3] *Compt. Rend.*, 120, 1,262.
[4] *Bull. Soc. Chim.* (3), 11, 362.

ture for half an hour, direct combination took place between the water and the acetylene, and aldehyde was formed.

Mixed Hydrates formed by Acetylene

It was also noticed by De Forcrand and Thomas,[1] in 1897, that at a temperature of 0° C. and under slight pressures in the presence of water, acetylene forms mixed hydrates with carbon tetrachloride, chloroform, ethylene dichloride, methyl iodide, bromoform, vinyl bromide, methylene chloride, and ethane trichloride; these hydrates decomposing with evolution of acetylene when the temperature is allowed to rise.

The action of Chlorine upon Acetylene

The action of chlorine upon acetylene was first noticed by its discoverer, Davy,[2] who in his original paper pointed out that when it is allowed to come in contact with chlorine gas, explosion instantly takes place, accompanied by a large flame and the deposition of much carbon, and he also points out that this action readily takes place in the dark, and is, unlike the combination of chlorine and hydrogen, independent of light. In 1860 Berthelot[3] stated that when acetylene and chlorine are mixed in diffused daylight, they detonate, with separation of carbon; but that under certain circumstances acetylene dichloride, $C_2H_2Cl_2$, may be formed, and no explosion occur. Nine years later Jungfleisch and Berthelot[4] showed that pentachloride of antimony unites with acetylene to form rhombic crystals having the composition $C_2H_2SbCl_5$.

Formation of Acetylene Dichloride

In 1884 Schlegel[5] found that when equal volumes of acetylene and chlorine were mixed in a strong glass tube, they might remain in contact for a considerable period in the dark without any reaction taking place, but that the light of a gas flame was sufficient to cause violent explosion of the mixture.

These apparent discrepancies were to a great extent

[1] *Compt. Rend.*, 125, 109. [2] *Brit. Assoc. Reports*, 1836, 62.
[3] *Compt. Rend.*, 51, 1,044.
[4] *Ann. Chem. Pharm.*, Sup. F., 225. [5] *Lieb. Ann.*, 226, 155.

explained by Roemer,[1] in 1886, who found that when pure acetylene is mixed with chlorine, no explosion takes place, and came to the conclusion that the explosions noticed by previous observers were caused by the presence of traces of polyacetylenes—such as the gaseous diacetylene C_4H_2—discovered and studied by Baeyer in the same year; but a far more likely explanation is that given by Mouneyrat,[2] who in 1898 found that when free from any trace of oxygen, acetylene and chlorine combine in diffused daylight to form acetylene tetrachloride, whilst if air or oxygen be present a violent explosion takes place.

Explanations given of the discrepancies between various observers

These various researches showed that acetylene unites directly with chlorine to form the di- and tetrachloride $C_2H_2Cl_2$ and $C_2H_2Cl_4$, whilst the work of Berthelot,[3] Berend,[4] and others, showed that the analogous compounds with bromine and iodine could be obtained.

Acetylene Di- and Tetra-chloride

In 1882 Plimpton[5] made an important research upon the halogen compounds of acetylene and the di-derivatives, of which the following is an extract.

Plimpton's work on the compounds of Bromine and Iodine with Acetylene

"By the action of bromine on acetylene Berthelot obtained a dibromide boiling at 130°, and a tetrabromide. Under ordinary conditions, however, when the gas is passed through bromine, the products are, as shown by Reboul (*Compt. Rend.*, 54, 1229) and Sabanejeff (*Annalen*, 178, 112), the tetrabromide and a small quantity of a solid body, C_2HBr_3, crystallising in laminæ, and melting at 174°.

Bromine compounds

By treating the tetrabromide mixed with its own volume of alcohol with zinc powder, as recommended by Sabanejeff (*Ber.*, 9, 1,441), a considerable quantity of dibromide was prepared. It boiled at 110–111°, and did not solidify at 17°. Its specific gravity at 0° was 2·268.

[1] *Lieb. Ann.*, 233, 215.
[2] *Bull. Soc. Chim.* (3), 19, 448.
[3] *Ann. Chim. Phys.* (4), 9, 426.
[4] *Ann. Chem. Pharm.*, 131, 122.
[5] *Journ. Chem. Soc.*, 41, 391.

Iodine compounds

The di-iodide was prepared by passing acetylene over iodine moistened with alcohol (Sabanejeff, *Annalen*, 178, 109). The absorption is very slow. On removing the iodine a semifluid mass was obtained, which, when crystallised from alcohol, yielded long elastic needles of the di-iodide, melting at 73°. This body is remarkably stable, and may be distilled without decomposition. Boiling point, 192° corr. On distilling the alcoholic mother liquor, a further portion of the solid iodide volatilised, together with some iodoform, and the residue, when precipitated with water, yielded a small quantity of the liquid isomeric iodide described by Sabanejeff. It solidified readily in ice.

The Di-derivatives of Acetylene

Acetylene chloriodide, C_2H_2ClI, may be prepared in the same way as the corresponding ethylene compound obtained by Maxwell Simpson (*Proc. Roy. Soc.*, 11, 590; 12, 278), by the absorption of acetylene by a solution of iodine monochloride in hydrochloric acid.

Properties of Acetylene Chloriodide

The chloriodide was obtained as a heavy liquid, becoming pink on exposure to light, with an odour like that of ethylene bromide. It boils at 119°—thermometer in vapour. Specific gravity at 0° = 2·2298.

Bromine displaces the iodine, yielding acetylene chlorobromide and other products.

Properties of Acetylene Chlorobromide

Acetylene chlorobromide is a volatile liquid with a pleasant ethereal odour, boiling at 81–82°. Specific gravity at 0° = 1·8157.

It is isomeric with the chlorobromethylene obtained by Hugo Muller (*Journ. Chem. Soc.*, 1864, 2, 420) by the action of potassium cyanide on chlorethylene bromide, and also by Denzel (*Lieb. Ann.*, 195, 206), who treated the same compound, $C_2H_3ClBr_2$, with alcoholic potash. The compound obtained by these chemists differs greatly from acetylene chlorobromide. It boils at 62°, has an excessively pungent odour, and polymerises with great ease. Its constitutional formula has been proved to be CHCl–CHBr, as, indeed,

might be expected from its mode of formation and boiling point.

Acetylene bromiodide is formed together with other products on passing acetylene through an aqueous solution of bromine iodide.

Acetylene Bromiodide

Acetylene bromiodide is a heavy, colourless liquid, which becomes red on exposure to light. Its specific gravity at 0°, when solid, is 2·750, and at 17·5°, 2·6272. It boils without decomposition at 150° corr., and solidifies at about 8°. Heated with alcoholic soda, it gives off a gas having the properties of bromacetylene."

Properties of Acetylene Bromiodide

In 1895 Caro [1] tried the action of acetylene on concentrated hydriodic acid and obtained acetylene di-iodide, which, on boiling with a concentrated solution of potassic hydrate, decomposed, yielding potassic acetate, acetylene, and alcohol. He stated that in this way he made 70 grs. of alcohol in one operation, and in a comparatively short period; whilst if the acetylene di-iodide be decomposed by moist silver oxide, only small quantities of acetylene result, and 90 per cent. of alcohol and potassic acetate are produced.

Caro's synthesis of Alcohol from Acetylene Di-iodide

He also states that if the acetylene di-iodide is heated in a closed tube with water, aldehyde is formed, of which he obtained 40 per cent. of the theoretical yield, and he considers that on a large scale the percentage would be even greater.

Action of heat on the Di-iodide and water

The importance of these observations caused Krueger and Pueckert [2] to repeat Caro's experiments with the greatest care, and they found that it took three months to make 50 grs. of the di-iodide, and that even when working with this quantity they were unable to detect the formation of alcohol, although they formed aldehyde and proved its presence by various reactions.

Krueger and Pueckert question Caro's result

Caro's reply [3] to this was that he had concluded that

[1] *Chem. Ind.*, 18, 226. [2] *Ibid.*, 18, 454.
[3] *Ibid.*, 18, 459.

an amount of alcohol should be formed equivalent to the potassic acetate found, and that on repeating his experiments he found he had been mistaken.

Berthelot's synthesis of Alcohol from Acetylene

Long before Berthelot[1] had stated that acetylene would combine with nascent hydrogen to form ethylene, but Krueger could not succeed in obtaining this reaction, otherwise the ethylene could be converted into alcohol by the action of sulphuric acid, and then of water,

$$C_2H_2 + H_2 = C_2H_4$$
$$C_2H_4 + H_2SO_4 = C_2H_6SO_4$$
$$C_2H_5SO_4H + H_2O = C_2H_6O + H_2SO_4\,;$$

and A. Frank[2] based a paper on the commercial manufacture of alcohol on this reaction, and attempted to show that alcohol could be obtained more cheaply from calcic carbide than from potatoes by the ordinary process of fermentation.

Action of Acetylene and Nitrogen under the influence of the induction spark

According to Berthelot,[3] acetylene mixed with nitrogen when exposed to the action of the induction spark yields hydrocyanic acid,

$$C_2H_2 + N_2 = 2HCN,$$

and the action is aided by the presence of about 10 per cent. of hydrogen, whilst Zeno[4] found that if a mixture of nitrogen dioxide and acetylene is passed through water, cyanic acid is formed,

$$C_2H_2 + 2NO = 2HCNO.$$

Dewar,[5] in 1877, recounted an experiment made by Ramsay, who found that by transmitting a mixture of acetylene and hydrocyanic acid through a red hot tube, pyridine bases were produced, whilst he himself found that by passing a mixture of acetylene and ammonia gas through a red hot tube, pyrrol might be

[1] *Compt. Rend.*, 54, 515. [2] *Chem. Ind.*, 18, 74.
[3] *Compt. Rend.*, 64, 35. [4] *Luce e Calore*, 1897, 118.
[5] *Proc. Roy. Soc.*, 26, 65.

formed synthetically. He notes, however, that the acetylene employed contained a small quantity of vinyl bromide, and it is possible that the reaction may have taken place between that body and ammonia. Only a small quantity of pyrrol is formed, the principal product being cyanide of ammonium.

Synthesis of Pyrrol from Acetylene and Ammonia

According to V. Meyer,[1] when acetylene is passed through boiling sulphur, thiophane is formed, whilst the action of sulphuric acid upon acetylene has been studied by several observers, and considerable differences of opinion have arisen, largely owing to impure acetylene being used in the experiments. Berthelot[2] found that on dissolving acetylene in sulphuric acid, with constant agitation, about a litre an hour is absorbed, and an acid is formed which yields an unstable barium salt, occasionally obtained as well-defined crystals, which he believed to be vinyl sulphate of barium, $Ba(C_2H_3SO_4)_2$. The vinyl sulphuric acid, $H(C_2H_3SO_4)$, was decomposed by boiling with water, yielding sulphuric acid and vinyl alcohol, C_2H_4O. The existence of this latter compound being very doubtful. Lagermark and Eltekoff,[3] in 1878, repeated Berthelot's researches and came to the conclusion that vinyl alcohol was not produced, but that it is croton aldehyde which is formed, a statement which Berthelot adversely criticised,[4] whilst Zeisel[5] showed that the acetylene used by Lagermark and Eltekoff had contained vinyl chloride, and that it was this impurity which had produced the croton aldehyde.

Formation of Thiophane

Action of Sulphuric Acid on Acetylene

Zeisel found that he could absorb 6 litres of acetylene by means of sulphuric acid in from 10 to 12 hours, but failed to obtain vinyl alcohol.

Absorption of Acetylene by Sulphuric Acid

Later, Berthelot[6] acted on acetylene with fuming

[1] *Berl. Ber.*, 16, 2176.
[2] *Ann. Chim. Phys.* (3), 57, 82.
[3] *Berl. Ber.*, 10, 687.
[4] *Bull. Soc. Chim.*, 27, 540.
[5] *Lieb. Ann.*, 191, 366.
[6] *Compt. Rend*, 64, 34.

Action of fuming Sulphuric Acid on Acetylene

sulphuric acid and obtained acetylene-sulphuric acid, which was not decomposed by water, and this substance, when melted with potassic hydrate, yielded phenol, so that it is probable that acetylene is first polymerised to benzol and then the sulphonic acid formed.

L. Schroter, in 1898,[1] tried the action of sulphuric acid containing 50 per cent. of sulphur trioxide upon acetylene, and got as a result acetaldehyde disulpho acid, decomposition products of this acid, *i.e.* methylene disulpho acid and formic acid, and also sulphates of acetaldehyde disulpho acid, whilst Erdmann, in 1898,[2] found that when acetylene was passed through a boiling solution of three volumes of sulphuric acid, with seven volumes of water, acetylene was transformed into aldehyde, the reaction being aided by adding some mercuric oxide to the liquid. He decomposed 125 grs. of calcium carbide with water, and the acetylene from this yielded 80 cc. of a 5 per cent. solution of acetaldehyde.

Formation of Aldehyde

Synthesis of Phenol from Acetylene

In 1898 also Berthelot[3] passed dry purified acetylene through sulphuric acid, containing $\frac{1}{3}$ of sulphur trioxide, for 18 hours; diluted with 15 volumes of water, and neutralised with potassic hydrate. After separation of the potassic sulphate, by crystallisation, and the addition of an equal volume of alcohol, the solution was concentrated and yielded an amorphous potassium acetylene sulfonate,

$$3C_2H_2 + 4SO_3 + 4KHO = (C_2H_2)_3(SO_4HK)_4,$$

which on heating for twenty minutes at a temperature of 180°–200° in an atmosphere of hydrogen, treating with cold dilute sulphuric acid, and distilling, yields phenol.

In 1899 Berthelot[4] analysed this potassium acety-

[1] *Lieb. Ann.*, 303, 114. [2] *Zeitsch. Anorg. Chem.*, 18, 48.
[3] *Compt. Rend.*, 127, 908. [4] *Compt. Rend.*, 128, 333.

lene sulfonate, and found that it corresponded to the formula,

$$(C_2H_2)_3(SO_4HK)_4,$$

and must be a salt of triacetylene tetrasulfonic acid.

He also attempted to obtain this body by the action of acetylene on ordinary sulphuric acid, but only obtained a very small quantity of the potassium salt from which traces of phenol were obtained.

It is evident from these researches that the action of sulphuric acid upon acetylene is of a very complex nature, and varies to a very great extent with the strength of acid used.

The action of Acetylene on other Hydro-carbons

The reactions of acetylene upon other hydrocarbons have not been much studied. Ramsay, in 1877,[1] when passing acetylene and hydrocyanic acid through a heated tube, found that picolyne was produced, but Ljubawin[2] failed to obtain this action. Prunier, in 1878,[3] found that when a mixture of acetylene with amylene and butylene is passed through a red hot tube, butyl acetylene and amyl acetylene are formed.

Action on Metals and Metallic Salts.

The action of Acetylene on metals and metallic salts

Mono- and Disodium and Potassium Acetylene

Berthelot has studied the action of sodium and some other metals upon the gas. He found[4] that when sodium is gently heated in acetylene, it is transformed into sodium acetylene, C_2HNa, whilst at a dull red heat disodium acetylene, C_2Na_2, is obtained, and under the same conditions potassium is transformed into dipotassium acetylene, C_2K_2. Both compounds are decomposed on contact with water, liberating acetylene; magnesium also probably gives a carbide under these conditions,[5] and iron decomposes acetylene with the formation of hydrocarbons, the liberation of hydrogen, and the deposition of carbon.

[1] *Phil. Mag.*, 52, 41.
[2] *Berl. Ber.*, 19, 481.
[3] *Ann. Chim. Phys.*, (5) 17, 5.
[4] *Compt. Rend.*, 62, 455.
[5] *Ann. Chim. Phys.*, 4, 9, 404.

Action of heat on Mono-sodium Acetylene

In 1898 numerous researches were made upon the action of metals with acetylene, and Erdmann and Koehner[1] found that the temperature needed to convert sodium when heated in acetylene into sodium acetylene, C_2HNa, is 190° C., and that at 210° C. this compound decomposes into disodium acetylene and acetylene, according to the formulæ,

$$2C_2HNa = C_2Na_2 + C_2H_2.$$

Metallic rhubidium does not act on acetylene gas, nor does zinc, mercury but little, whilst metallic iron, when heated in acetylene, gives products of polymerisation. Moissan[2] also found that the white compound obtained by the action of acetylene on sodium at common temperatures was a monosodic carbide, or sodium acetylene, C_2HNa, and that on heating this, acetylene is evolved and disodium acetylene or sodium carbide is produced, whilst if the temperature be still further raised until the hard glass softens, this compound is again entirely decomposed into sodium and carbon.

Later on he found[3] that when acetylene acts on an ammoniacal solution of sodiumammonium at $-40°$, there are formed transparent crystals, and the temperature falls to $-60°$. Moissan believes this action to be,

$$3C_2H_2 + 2NaNH_3 = 2C_2NaH + 2NH_3 + C_2H_4.$$

The monosodium acetylene and ethylene were carefully determined, and further experiments showed that the crystals obtained are in reality a compound of sodium carbide and acetylene, Na_2C_2, C_2H_2, and this breaks up by dissociation, forming the monosodium acetylene,

Compound of Di-sodium Acetylene with Acetylene

$$Na_2C_2,C_2H_2 = 2C_2HNa.$$

He prepared a similar compound of potassium carbide

[1] *Zeitsch. Anorg. Chem.*, 18, 48. [2] *Compt. Rend.*, 126, 302. [3] *Ibid.*, 127, 911.

Compounds of Carbides with Acetylene and Ammonia

with acetylene, K_2C_2,C_2H_2, but found that when lithium was used the reaction was of a different character; well-formed crystals were obtained and were found to consist of a compound of lithium carbide, acetylene and ammonia, $Li_2C_2,C_2H_2,2NH_3$, and a similar crystalline compound of calcic carbide, acetylene and ammonia was also formed.

In the formation of these bodies ethylene is liberated, and both compounds burn in carbon dioxide and also in chlorine.

Davy's preparation of Acetylene from Potassium Carbide

It will be remembered that Davy first made acetylene by acting with water upon a black residue left in the retorts used for the manufacture of potassium by igniting potassium tartrate, and this compound was examined by Berzelius,[1] who came to the conclusion that it was potassium carbide. Liebig,[2] however, found that a compound having somewhat similar properties was formed when carbon monoxide is passed over potassium, heated just to melting, and Brodie[3] confirmed the results obtained by Liebig, and, further, showed that 28 parts by weight of carbon monoxide are absorbed by 39·1 parts of potassium, so that the compound is probably potassium carbonyl. This body is a greyish solid, extremely explosive, decomposes water, and is resolved at a red heat into potassium and carbon monoxide. Some authorities, notably Watt's Dictionary (new edition, Morley and Muir), consider that Liebig's potassium carbonyl is the same substance as the material from which Davy first prepared acetylene, which is an evident error, as the body was obtained from the retort itself, and had been subjected to a temperature which would have entirely decomposed the carbonyl compound. Moreover, Davy's analysis shows the gas formed by the decomposition of water in contact with it to have been practically

Potassium Carbonyl

Confusion between Potassium Carbide and Potassium Carbonyl

[1] *Pogg. Ann.*, 4, 31. [2] *Lieb. Ann.*, 11, 182.
[3] *Chem. Journ.* 12, 269.

pure acetylene, whilst the gaseous mixture evolved by the action of potassium carbonyl on water would be carbon monoxide and hydrogen. The latter compound is formed in the condenser of the potassium plant, as the vapours condense to liquid potassium, and occasionally choke the leading tube, whilst Davy's compound was left as a residue in the retort, and must have been either potassium acetylene, K_2C_2, as stated by Berzelius, or a mixture of this compound with calcic carbide formed from the lime always present as an impurity in crude potassic tartrate.

Compounds of Acetylene with other metals

The most studied metallic compounds formed by acetylene have been the copper, silver and mercury acetylenes.

Copper Acetylene noticed by Torrey in 1839

It was as early as 1839 that Torrey [1] noticed a dark-brown compound in the copper gas mains of New York, and found that it exploded when struck by a hammer, or when heated to 200°; he had no idea, however, of its composition, and it was not until 1862 that it was realized that this body was a compound due to acetylene. In that year Crova [2] found that metallic copper became coated with a brownish film when exposed to a mixture of acetylene and air, and that finely-divided copper, under the same conditions, forms copper acetylene, the action being aided by the presence of ammonia.

Nicklès [3] also noticed the formation of copper acetylene in gas pipes made of copper, but no compound of a like character in iron or lead pipes.

The red precipitate formed when Acetylene is passed through Ammoniacal Cuprous Chloride

Quet, Boettger, and Vogel,[4] had already noticed the formation of a red precipitate when acetylene was passed through ammoniacal cuprous chloride, and had studied its properties, but it was Berthelot,[5] who, in 1862, first attempted to determine its composition, and

[1] *American Gas Light Journ.*, Oct., 1859.
[2] *Compt. Rend.*, 55, 435.
[3] *Ibid.*, 55, 505.
[4] See chap. i., p. 15.
[5] *Compt. Rend.*, 54, 1044.

came to the conclusion that it was a monocuprous acetylene, mixed with a varying proportion of cupric oxide, and gave it the formula $C_2CuH_4 + nCuO$. He further found that when acetylene is passed through a concentrated solution of cuprous chloride in potassic chloride, a yellow crystalline precipitate of cuprous vinyl chloride C_2HCu_2Cl is formed, and he obtained corresponding bromides and iodides by a similar process.

Delicacy of this reaction as a test for Acetylene

Four years later[1] he further investigated the precipitate formed by acetylene in ammoniacal cuprous chloride, and found that the reaction was so delicate that one two-hundredth of a milligram of acetylene diluted with hydrogen gives a red precipitate, and he now gives the formula of the true compound as $2(C_2Cu_2H)O$.

Attempts to determine the composition of the red precipitate

Whilst Berthelot had been making these researches, Reboul[2] had also investigated the compound, and found no oxygen in it, and gave its composition as being C_2CuH.

In 1874, Blochmann[3] attacked the problem of its composition, and having analysed it, declared it to be $C_2H_2Cu_2O$, a formula that was generally accepted.

Action of Hydrochloric Acid on Copper Acetylene

The formation of the body he represents by the equation—

$$Cu_2Cl_2 + 2NH_3 + H_2O + C_2H_2 = C_2H_2Cu_2O + 2NH_4Cl,$$

and its decomposition by hydrochloric acid as—

$$C_2H_2Cu_2O + 2HCl = C_2H_2 + Cu_2Cl_2 + H_2O.$$

Sulphuric Acid does not liberate Acetylene from the red precipitate

In 1886 Roemer[4] pointed out that copper acetylene cannot be decomposed with evolution of acetylene by sulphuric acid. If the acid is weak, it does not act upon it, whilst strong acid gives many products but practically no acetylene.

[1] *Compt. Rend.*, 62, 455.
[2] *Ibid.*, 54, 1229.
[3] *Lieb. Ann.*, 173, 176.
[4] *Ibid.*, 233, 183.

Keiser,[1] in 1892, noted that the precipitate obtained by passing acetylene through ammoniacal cuprous chloride always contained small traces of carbon, which were left after decomposing it with hydrochloric acid.

Keiser shows the red precipitate to be Copper Acetylene, Cu_2C_2

He found that he obtained the purest copper acetylene by passing the gas through cuprous hydrate suspended in water, and that it contained 83·36 to 83·96 per cent. of copper, a result which led him to adopt the formula—

$$Cu_2C_2,$$

which requires 84·08 per cent. of copper.

He found, by exploding the compound in a vacuum, that it contained no hydrogen.

C. Phillips [2] pointed out that the compound must be kept from contact with air, as otherwise the yield of acetylene, obtained by decomposing it with hydrochloric acid, is much diminished, and he proposed washing and filtering the precipitated copper acetylene in an atmosphere of carbon dioxide.

Action of Acetylene on Cupric Salts

In 1897 Soederbaum [3] noted that the action of acetylene on cupric salts seemed, for the most part, to have been disregarded, although, on passing a stream of the pure gas into an ammoniacal solution of either cupric sulphate or nitrate, a black flocculent precipitate was slowly produced.

This substance, after being dried over sulphuric acid, gave various results, on analysis, a fact which was found to be due to the absorption of oxygen from the air during the process of drying; in an exhausted desiccator, however, the substance ceased to increase in weight after two days, and then yielded, on analysis, numbers corresponding with the formula $(C_{17}Cu_8H_4O_3)n$. This copper acetylene is a black, amorphous powder, insoluble in water and organic solvents; it explodes

[1] *Amer. Chem. Journ.*, 14, 285. [2] *Zeit. Anorg. Chem.*, 6, 255.
[3] *Berl. Ber.*, 30, 760.

between 70° and 80° when heated, and decomposes quickly on heating with hydrogen chloride with formation of the halogen salt of copper, and a carbonaceous residue of the formula $(C_{12}H_4O_3)n$; this is probably similar to the graphite hydrate obtained by Schuetzenberger and Bourgeois from crude iron.

On passing acetylene into a neutral or faintly acid solution of copper acetate, a precipitate is formed corresponding in composition with the formula $(C_8Cu_4O)m + (H_2O)n$, and differing from the compound above mentioned in being stable in air and non-explosive. It seems, therefore, from these experiments that a large number of copper acetylenes are capable of existing.

Action of Acetylene on Anhydrous Cupric Chloride

A. Hofmann and Kuespert[1] found that the compound $(Cu_2Cl_2)_2.C_2H_2$, obtained by the action of pure acetylene on a solution of anhydrous cupric chloride in absolute alcohol, crystallised in colourless needles; the same compound is also obtained when methylic alcohol is employed, but the substance then crystallises in forms resembling those of Karlsbad feldspar. When treated with water, it is converted into copper acetylene, whilst with hydrochloric acid it is decomposed into acetylene and cuprous chloride. The reduction of the cupric chloride is due to the action of the acetylene, for by mixing the alcoholic filtrate from the crystals with water, and extracting the mixture with ether, an oily liquid is obtained which yields acetylene when treated with zinc. The compound is not explosive. If 75 per cent. alcohol is employed in the preparation, a reddish-brown powder is obtained, which is slightly explosive, and, when treated with hydrochloric acid, yields acetylene, cuprous chloride and a black residue.

Conditions under which Copper Acetylene becomes explosive

During 1898 a large amount of work was done upon the copper compounds. May[2] found that freshly-made

[1] *Zeit. Anorg. Chem.*, 15, 204. [2] *Journ. f. Gasbel.*, 41, 683.

copper acetylene could be heated to 60°, and even higher, without explosion, but that explosion always takes place under these conditions if the copper acetylene has been exposed to air for a few hours.

He also notices that when copper acetylene has been gently warmed in a current of oxygen, it explodes on contact with acetylene, and he concludes that the oxygen converts the compound into copper diacetylene, which afterwards interacts with more acetylene. //

Compound of Acetylene with Cuprous Chloride discovered by Chavastelon

Chavastelon[1] found that when cuprous acetylene is treated with hydrochloric acid in the cold, there is no appreciable evolution of gas, a fact which is attributed to the formation of a compound of acetylene with cuprous chloride, which is decomposed on warming. This compound, which analysis shows to have the composition C_2H_2,Cu_2Cl_2, may be prepared (1) by passing acetylene into a saturated solution of cuprous chloride in dilute hydrochloric acid—HCl and $10H_2O$ to HCl and $7H_2O$—maintained at a temperature not exceeding 12°; (2) by the action of acetylene on an aqueous or alcoholic solution of cuprous chloride—20 to 40 per cent.—in presence of metallic copper. By the first and most suitable method the substance is obtained in the form of large hexagonal prisms belonging to the orthorhombic system; and by the second in silky needles, which are liable to contamination by a violet purple deposit, which is produced at the commencement of the reaction. In order to isolate the crystals unchanged, they must be quickly washed with absolute alcohol and anhydrous ether, both of these liquids having been previously cooled to 0° and saturated with acetylene, and finally dried in a current of acetylene. The crystals soon alter by exposure to air, and are immediately decomposed by water or solutions of alkali chlorides, with evolution of acetylene, and the production of the violet purple substance above men-

[1] *Compt. Rend.*, 126, 1810.

tioned, the nature of which is being investigated. On warming they dissociate without explosion, and the following measurements of the pressure at different temperatures have been made:—

Effect of warming on the double compound

Temperature.	Pressure.	Temperature.	Pressure.
0°	3 mm.	46°	220 mm.
20	25	60	480
30	50	78	2620
40	131		

The compound described above is different from that prepared by Hofmann and Kuespert, which Chavastelon was unable to obtain.

The violet compound prepared by the action of water on $C_2H_2Cu_2Cl_2$

Later, Chavastelon found that[1] the crystalline compound of acetylene with cuprous chloride, $C_2H_2Cu_2Cl_2$, is decomposed by water with production of a violet compound. Acetylene is at the same time slowly liberated, and the liquid found to contain free hydrochloric acid, which limits the decomposition. The violet substance is best prepared by digesting the compound C_2H_2,Cu_2Cl_2, with a large excess of water saturated with carbonic anhydride out of contact with air. The crystals are washed with absolute alcohol and anhydrous ether, and finally dried over calcium chloride in an atmosphere of carbonic anhydride.

Composition of the violet compound

Estimation of the copper and chlorine, and the measurement of the volume of acetylene which the compound yields when treated with concentrated hydrochloric acid, show that it has the composition C_2H_2,Cu_2Cl_2,Cu_2O.

Action of finely divided Copper on Acetylene

Erdmann and Koehner[2] came to the conclusion that when acetylene is passed over finely-divided copper heated to 400°–500°, it is decomposed into hydrogen and carbon, the latter being deposited in the graphitic condition. At lower temperatures—below 250°—the copper combines with the gas to form a yellowish-brown compound, which, unlike Soederbaum's cupric

[1] *Compt. Rend.*, 127, 68. [2] *Zeit. Anorg. Chem.*, 1898, 18, 48.

New compound of Carbon and Hydrogen with Copper

acetylene, is not explosive. The new substance is more conveniently prepared by heating finely-divided cuprous oxide in a current of acetylene at 250°; it is exceedingly voluminous, and its composition corresponds with the formula $C_{44}H_{64}Cu_3$; when heated with excess of zinc dust, it yields 20 per cent. of an oil boiling between 190°–250°, and possessing an odour like Caucasian naphtha. If the mixture is heated to a higher temperature, aromatic hydrocarbons appear in the distillate, and naphthalene is obtained, whilst a portion which dissolves in caustic soda has properties resembling those of cresol.

Acetylene as an analytical reagent

It is evident that the extreme delicacy of the reaction between ammoniacal cuprous salts and acetylene not only gives an extremely delicate test for the latter gas, but also, as has been pointed out by Soederbaum,[1] makes acetylene a useful analytical reagent, and offers an easy method for the separation of copper from cadmium.

The explosion of Copper Acetylene does not detonate Acetylene

In 1898 Freund and May[2] found that when a few centigrammes of copper acetylene, dried in air for four to five hours at 50°–60°, were introduced into a combustion tube, and a slow current of acetylene was passed through the tube, an explosion with evolution of light took place. This explosion was always local, and did not propagate backwards in the gas. The phenomenon took place with commercial as well as with carefully purified acetylene.

Explosion due to Copper Diacetylene

It was observed that only copper acetylene dried in contact with air behaved in this way. If dried in a vacuum or in a current of carbon dioxide, the compound will not explode. It seems that the oxygen of the air forms copper diacetylene—

$$\begin{array}{l} CH \equiv C - Cu - Cu - OH \\ CH \equiv C - Cu - Cu - OH \end{array} + O = H_2O + \begin{array}{l} C \equiv C - Cu - Cu - OH \\ | \\ C \equiv C - Cu - Cu - OH \end{array}$$

[1] *Berl. Ber.*, 30, 902. [2] *Acet. Wiss. Ind.*, 1, 285.

This observation agrees with May's previous paper. It seems evident from these various researches that acetylene forms with copper and copper salts a number of compounds ranging from the copper carbide, Cu_2C_2, up to the complex bodies noted by Soederbaum, the composition of these products varying with the concentration and character of the solutions used, and the presence or absence of air.

Action of Acetylene on the Ammoniacal Cuprous Chloride Solution

There is but little doubt that the reddish-brown precipitate formed when acetylene is passed through ammoniacal cuprous chloride is true copper acetylene, Cu_2C_2, a non-explosive body which yields acetylene on treatment with hydrochloric acid. It is, however, intensely oxidisable, and on contact with air absorbs oxygen, becoming explosive; and it is the presence of varying quantities of oxidation products that has given rise to the differences observed by various experimentalists.

Action of Acetylene on Silver Salts

It was in 1858 that Quet[1] first noticed the precipitate formed when acetylene was passed through an ammoniacal solution of a silver salt, and found that when dry it was of an explosive character; and in the same year Vogel and Reischauer[2] determined the amount of silver present in it as being from 78·3 to 84 per cent. Boettger[3] also, in 1859, noticed the formation of this body; whilst Miasnikoff,[4] in 1861, gave the formula for it as C_4H_4Ag, and Berthelot, in 1866, gave its composition as being $(C_2HAg_2)O$. Berend,[5] in the same year, calculated from determinations made by Reboul[6] that its composition must be $(C_2HAg)_2,Ag_2O$, and in 1874 Blochmann,[7] after careful determinations, gave it the formula C_2H_2,Ag_2O, corresponding to the copper compound C_2H_2,Cu_2O, and

[1] *Compt. Rend.*, 46, 903.
[2] *Jahr. Ber.*, 11, 208.
[3] *Ann. Chem. Pharm.*, 109, 351.
[4] *Ibid.*, 118, 330.
[5] *Ibid.*, 135, 258.
[6] *Compt. Rend.*, 54, 1229.
[7] *Ann. Chem. Pharm.*, 173, 174.

also stated that the silver compound is more explosive than the copper acetylene.

Keiser shows the composition of the Silver precipitate to be Ag_2C_2

This view of its composition was the one generally accepted until 1892, when Keiser[1] brought an investigation upon this body before the Franklin Institute, and showed that when pure acetylene is conducted into an ammoniacal solution of silver nitrate, the yellowish-white precipitate which is formed has, when dried, the composition represented by the formula C_2Ag_2. It may, in fact, be regarded as acetylene in which both hydrogen atoms have been replaced by silver. The formula that has been generally adopted for this substance is $C_2H_2Ag_2O$. But such a compound contains only 83·71 per cent. of silver, whereas in three specimens of the substance prepared by Keiser the quantity of silver found was 89·32, 89·44 and 89·60 per cent. The formula C_2Ag_2 requires 89·9 per cent. silver. That the compound contains no hydrogen was shown by exploding a weighed quantity of it in a glass tube which had been exhausted with an air pump; no hydrogen was obtained. In the same year Plimpton[2] published his researches on the metallic derivatives of acetylene, and says: "The precipitate formed by acetylene in ammoniacal silver nitrate is in dilute solutions—decinormal—bright yellow. In strong solutions the yellow curdy substance first thrown down is prone to pass into a white and less bulky form. The yellow substance often undergoes the same change when allowed to stand under water containing acetylene and protected from light. The white substance usually yields a somewhat higher percentage of silver. Strong ammonia appears to be without action on the yellow acetylide, and the quantity present during precipitation does not influence the composition of the precipitate."

Plimpton's experiments with the Silver compounds

[1] *Amer. Chem. Journ.*, 14, 185. [2] *Proc. Chem. Soc.*, 1892, 109.

Silver estimations in eight specimens dried over sulphuric acid gave percentages of silver ranging from 87·38 to 88·85. Of these, two had been dried for three and six weeks respectively, and yielded 88·7 and 88·8. Blochmann's formula, $C_2Ag_2H_2O$, requires 83·7; that of Berthelot, $C_2Ag_2,\frac{1}{2}H_2O$ or $(C_2HAg_2)_2O$, 86·7.

An attempt to prepare silver acetylene in neutral or acid solution, so as to diminish the risk of the precipitate carrying down with it silver oxide, was successful. Silver acetate was wholly precipitated by acetylene with separation of the whole of the acetic acid. The acetylene so prepared had the same properties as that obtained in ammoniacal solution, but had not the same tendency to turn brown on drying, and, like the latter, separated as a yellow curdy precipitate, but became white under the same conditions.

The silver was estimated in fifteen specimens, carefully dried in a vacuum over sulphuric acid until they ceased to lose weight, and in some cases at 60°–70°. The results lay between 86·6, the percentage of silver required for $C_2Ag_2,\frac{1}{2}H_2O$, and 87·9, nearly that required for $C_2Ag_2,\frac{1}{3}H_2O$, 87·8.

Silver compound always contains water

Drying at 60°–70° caused a slight loss of weight, but darkened the precipitates. Those specimens which had become white yielded higher results than those which remained yellow. Two portions of the same precipitate, of which the one was left in contact with strong ammonia for several days, were dried, and yielded the same percentage of silver, 86·56.

The acetylene given off from a known weight of the dry substance with chlorhydric acid was measured, and the silver chloride weighed: ratio of silver to acetylene as 38 to 20, or 10·3 per cent.; carbon, $C_2Ag_2,\frac{1}{3}H_2O$, 9·7; percentage of silver, 87·47. Other experiments by the same method, made with the compound from ammoniacal silver nitrate and from silver

acetate, also gave one molecule of acetylene to two atoms of silver.

Silver chloride dissolved in ammonia gave a yellow compound containing 87·85 per cent. silver, and free from silver chloride.

Silver nitrate in aqueous solution—decinormal—is precipitated by acetylene, three-fourths of the acid being liberated. Precipitates prepared from solutions of different strengths contained varying proportions of silver nitrate.

Double Salts of Silver Acetylene and Silver Nitrate

Alcoholic silver nitrate yields a precipitate much richer in nitrate, containing equal amounts of silver as acetylene and as nitrate. The action of hydrocarbons of the acetylene series on alcoholic silver nitrate has been studied by Behal. The analyses of precipitates from the nitrates gave as limits $3C_2Ag_22AgNO_3Aq$ and $C_2Ag_22AgNO_3Aq$, the latter being obtained from alcoholic solutions.

Double Salt of Silver Acetylene and Silver Sulphate

Silver sulphate solutions are also completely precipitated by acetylene, and with a solution containing 0·2 gr. in 100 cc. two-thirds of the sulphuric acid was set free. Precipitates obtained from such a solution gave results corresponding to $2C_2Ag_2Ag_2SO_4Aq$.

Chavastelon's researches on Silver Acetylene

Chavastelon[1] studied the action of silver acetylene on silver nitrate, and found that when acetylene is passed into an aqueous solution of silver nitrate, a white precipitate is formed, and the acidity of the liquid increases somewhat rapidly, until all the silver nitrate has been precipitated, after which it increases slowly. In presence of an excess of the silver salt the quantity of free nitric acid is always higher than that which corresponds with the quantity of silver nitrate that has disappeared. The acetylene compound combines with some silver nitrate as such, and the quantity of silver nitrate decomposed is twice as great as that which enters into combination in this

[1] *Compt. Rend.*, 124, 1364.

way. Experiments with definite volumes of acetylene, combined with an analysis of the precipitate, show that the first compound formed has the composition $C_2Ag_2,AgNO_3$. It is decomposed by the prolonged action of acetylene, or by hot ammonia solution, the silver nitrate being decomposed or dissolved, whilst silver acetylene, C_2Ag_2, is left. The action of acetylene on an ammoniacal solution of the silver salt yields silver acetylene at once, as Keiser stated. These results are analogous to those obtained by Bruylants and Behal with hydrocarbons derived from acetylene by substitution.

Arth[1] also made a research on these compounds, and points out that silver acetylene is variously described as yellow and white. In reality, the precipitate formed on passing the gas through an ammoniacal solution of silver nitrate is at first yellow, but subsequently becomes colourless, even when excess of the hydrocarbon is employed. The compound C_2Ag_2, $AgNO_3$ becomes deep yellow when treated with ammonia, but soon becomes colourless.

Conditions under which the Silver Acetylene and the Double Salts are produced

Silver acetylene C_2Ag_2 is always produced when excess of acetylene is passed through an ammoniacal solution of silver nitrate, but the compound C_2Ag_2, $AgNO_3$ is formed in ordinary aqueous solutions, and is pure only when these are sufficiently concentrated. An N/2 solution of silver nitrate yields a colourless product, and the precipitate does not begin to be yellow until the dilution reaches N/24, the quantity of nitric acid set free increasing with the dilution. It therefore appears that the initial action of acetylene on a neutral solution of silver nitrate gives rise to the compound $C_2Ag_2,AgNO_3$, which is converted into a yellow intermediate compound of unknown composition capable of existence in presence of ammonia, this substance ultimately yielding silver acetylene.

Arth's conclusions as to the Double Silver Salts

[1] *Compt. Rend.*, 124, 1534.

Silver acetylene and the compound $C_2Ag_2,AgNO_3$ dissolve readily in a solution of potassium cyanide, acetylene being regenerated.

The action of Acetylene on Mercury Salts

The action of acetylene on mercury salts was first noticed in 1869 by Basset,[1] who found, when passing acetylene through a solution of mercuric iodide in potassic iodide and potassic hydrate, that a light-coloured precipitate, having explosive properties when dried, is formed and can be decomposed by hydrochloric acid with evolution of acetylene. He ascribes to this compound the composition C_2H,HgI,HgO.

Formation of Alcohol from the Mercury compound

In 1883 Kutscherow[2] noted that when acetylene is passed through a solution of mercuric chloride a precipitate is obtained, which, when treated with hydrochloric acid, yields aldehyde, which can be readily converted by reduction into alcohol.

The compounds of Acetylene with Mercury Salts, and the action of Iodine upon them

In 1892 Plimpton[3] showed that mercuric acetate solutions yield white precipitates, which become grey towards the end of the precipitation. If the solutions are not too strong, the whole of the metal is thrown down with separation of the acetic acid. When washed with alcohol, and dried in vacuo over sulphuric acid, the substance has the composition required by the formula $3HgO2C_2H_2$. It resembles the compound $3HgO2C_3H_43HgCl_2$ obtained by Kutscherow from allylene, for, unlike the acetylides generally, it does not give off acetylene on treatment with hydrochloric acid, and is not explosive

Iodine attacks it apparently with formation of iodoform.

Mercurous acetate freshly precipitated and suspended in water is decomposed by acetylene, and is converted into a greyish substance which differs entirely from the mercuric compouud, and seems to be similar to silver acetylene in composition and properties. It

[1] *Zeit. f. Chem.*, 1869, 314. [2] *Berl. Ber.*, 17, 13.
[3] *Proc. Chem. Soc.*, 1892, 109.

detonates when heated suddenly, and gives acetylene on treatment with hydrochloric acid. Iodine acts upon it in the same way as upon silver acetylene, yielding di-iodacetylene.

The acetylene used was prepared from the copper compound obtained from the incomplete combustion of coal gas, and was purified by caustic soda.

The researches of Travers and Plimpton on the Mercury compounds of Acetylene

Berthelot and Keiser[1] both made experiments upon this compound, and in 1894 Travers and Plimpton,[2] in a review of their work, say, "Berthelot (*Ann. Chim. Phys.*, 4, 9, 386) by passing acetylene through a solution of mercuric iodide in potassium iodide made alkaline with ammonia, obtained an explosive mercury acetylene, of which, however, he seems to have made no analysis. The authors have prepared this substance in various ways, and studied its composition and properties. They have prepared it by the action of acetylene: (1) on freshly precipitated mercuric oxide; (2) on solutions of mercuric cyanide mixed with ammonia, or, better, with ammonia and cupric sulphate or zinc chloride; (3) on solutions of mercuric acetate or sulphate with ammonia, when a part only of the mercury is precipitated; (4) on mercuric oxide dissolved by the aid of ammonia and ammonium carbonate. The latter method is the most convenient. The heavy white powder which separates is well washed and dried at 100°. Analysis gives as the means of four determinations: mercury, 87·1; carbon, 10·1 and 10·3. Calculated for $3C_2HgH_2O$: mercury, 87; carbon, 10·4 per cent. The substance could not be obtained free from water, even after long drying at 100°. Mercuric acetylene seems to belong to the same class of bodies as the silver and copper acetylenes; it is explosive, yields part of its carbon as acetylene when warmed with chlorhydric acid, and part as aldehyde, and yields the compound C_2I_2, and eventually C_2I_4 when acted on by iodine

[1] *Amer. Chem. Journ.*, 15, 535. [2] *Proc. Roy. Soc.*, 1894.

dissolved in potassium iodide. It differs altogether from the substance obtained from solutions of mercuric acetate described in a previous note—*Proc. Chem. Soc.*, 1892, 109—which is non-explosive, and in other respects resembles the allylene derivatives obtained by Kutscherow from solutions of mercuric chloride and acetate (*Ber.*, 17, 13). Mercuric acetylene detonates violently when suddenly heated or struck sharply; it can, however, be handled with safety even when dry.

Mercuric Acetylene, C_2Hg

"Keiser, who had apparently overlooked Berthelot's description of the substance, and the note published in the *Proc. Roy. Soc.* by one of the authors, has recently —*Am. Chem. Journn.*, Nov., 1893—obtained the same substance, and attributes to it the formula C_2Hg; the authors have not been able to obtain either this or the silver compound free from water."

Purification of Acetylene by Acid Mercuric Chloride Solution

Bergé and Reychler[1] in 1897 suggest the purification of acetylene made from calcium carbide by passing it through a solution containing—

Water	80 grams.
Hydrochloric acid . .	20 ,,
Mercuric chloride . .	8–12 ,,

which they say does not act on the acetylene, but purifies it from phosphuretted hydrogen.

Biginelli,[2] in 1898, makes an acetylene mercuric chloride $Cl-CH=CH-HgCl$, whilst Erdmann and Koehner[3] identified mercuro-acetylene nitrate, HgC,CHg,Hg,NO_3+H_2O, produced by saturating a hot solution of mercuric nitrate with acetylene. It separates in small white crystals, and differs from Keiser's silver analogue $C_2Ag_2,AgNO_3$ in containing H_2O. It resembles Poleck and Thummel's mercury derivative of

Double Mercury Salts

[1] *Bull. Soc. Chim.*, 3, 17, 218.
[2] *Ann. di Farm. e Chim.*, 1898, 16.
[3] *Zeit. Anorg. Chem.*, 18, 48.

vinyl alcohol, and yields acetaldehyde on treatment with dilute acids.

Acetaldehyde is produced when acetylene is passed through mercuric oxide, suspended in boiling phosphoric acid of sp. gr. 1·15, or in 30 per cent. sulphuric acid.

Hoffmann's results

According to K. Hoffmann,[1] acetylene, when passed through a solution of mercuric nitrate, acidified with nitric acid, yields a fine, colourless, crystalline precipitate, which, after washing with 2 per cent. nitric acid, and drying under reduced pressure, has the composition $C_2Hg_2NO_4H$. If the gas be passed through the solution for several hours, a black substance is also formed. It is practically insoluble in water, or in dilute—3 per cent.—nitric acid, but is decomposed by concentrated acid. With warm dilute hydrochloric acid it yields acetaldehyde, and mercuric chloride goes into solution. When treated with alkalis the nitrogen is obtained in the form of nitrates, and when warmed with sodium hydroxide and potassium cyanide solution, aldehyde resin is formed. The compound may be obtained in the form of large crystals by using an alcoholic solution of aldehyde in place of acetylene; after remaining for fourteen days, large, colourless, double-refractive prisms, terminated by pyramids, are deposited. The constitution suggested is $NO_3,Hg,C(:Hg),CH:O$.

Hoffmann's criticism of Erdmann and Kochner's results

Later in the year Hoffmann[2] criticizes Erdmann and Koehner's results, and says they describe a substance obtained by the action of acetylene on a hot solution of mercuric nitrate as a double compound of mercurous carbide and nitrate, $HgC:CHg,HgNO_3 + H_2O$. It is not an acetylide, however, for it gives no acetylene when heated with hydrochloric acid, but aldehyde instead. Neither is it a mercurous compound, for when it is digested for half an hour with dilute hydrochloric acid, 83·8 per cent. of mercuric chloride is formed, but only

[1] *Berl. Ber.*, 31, 2212. [2] *Ibid.*, 31, 2783.

2·3 per cent. of mercurous chloride, and this is no doubt on account of the reducing action of the aldehyde simultaneously formed; further, potassium cyanide solution dissolves the compound without decomposition of mercury, and ammonia produces no black coloration. The substance analysed by Erdmann and Koehner contained a little mercury; after removal of this by digestion with dilute nitric acid, the analytical numbers agree with the formula $NO_2,Hg,O(:Hg_2:O),CHO$, that of a substituted aldehyde.

The compound is best prepared by dissolving yellow mercuric oxide—20 grams—in dilute nitric acid—70 cc. of 30 per cent. acid, and 500 cc. of water—filtering, and passing a fairly rapid current of acetylene for two hours through the solution, at a temperature of 18°. The precipitate is then collected, digested three times with 8 per cent. nitric acid—150 cc.—at the ordinary temperature for six hours, filtered, washed with alcohol and ether, and dried under diminished pressure over sulphuric acid.

The action of Acetylene on metals

The action of acetylene upon metals has attracted a fair share of attention. Moissan and Mourreu[1] have shown that acetylene acts readily at the ordinary temperature on iron, nickel, and cobalt, if they have been reduced from their oxides at the lowest possible temperature.

Action with Iron, Nickel, and Cobalt

There is great development of heat, and if the current of gas be rapid, the metal becomes incandescent. Part of the acetylene is converted into benzene, and other polymerides, but the greater part splits up into carbon and hydrogen.

It would seem that the phenomena are due to the energetic absorption of the gas by the porous reduced metal; heat is thus developed, part of the acetylene is polymerised, and part is decomposed. As soon as decomposition begins, the reserve energy of the acetylene becomes available, and contributes to the energy

[1] *Compt. Rend.*, 122, 1240.

Action of spongy Platinum

of the reaction. Carefully prepared spongy platinum produces a similar decomposition. On the other hand, if the acetylene is diluted with nitrogen there is no incandescence, although the acetylene is absorbed and slightly decomposed.

If the metals have been heated at too high a temperature during the process of reduction, heat is necessary in order to start the decomposition of the acetylene.

Action of reduced Nickel on Acetylene

Sabatier and Sinderens[1] find that when nickel, reduced by hydrogen, is exposed to a current of ~~hydrogen~~ at 300°, the acetylene is decomposed, and hydrogen and methane are formed.

The early observations made by Torrey[2] and Niclés[3] on the formation of explosive deposits in copper gas-pipes, owing to the trace of acetylene present, led to the expectation that this gas would act readily upon copper and similar metals. Experiments, however, show that this is not the case.

Experiments by Gerdes upon the action of Acetylene on ordinary metals and alloys

In the summer of 1895 H. Gerdes,[4] the chief engineer of Messrs. Pintsch, of Berlin, made an exhaustive series of experiments upon this point, not only with the gas under ordinary pressure, but with mixtures of acetylene with oil and coal-gas at pressures of nearly ten atmospheres.

This was done by placing the metals to be tested in steel cylinders, the slips being fitted in wooden frames so arranged as to prevent any contact either between the individual metals or the walls of the metal cylinder. Two of these cylinders were filled with pure acetylene, two with a mixture of 80 per cent. of acetylene and 20 per cent. of oil-gas, and one with a mixture of acetylene with 20 per cent. coal-gas ; a small quantity of water being placed into each cylinder in

[1] *Compt. Rend.*, 124, 616.
[2] *Amer. Gaslight Journ.*, Oct., 1859.
[3] *Compt. Rend.*, 55, 505.
[4] *Journ. f. Gashel.*, 40, 201.

order that the gas should be moist, as it was expected that this would greatly facilitate the action upon the metals. These cylinders were filled with the gases at a pressure of nine to ten atmospheres, and they were exposed on the roof of a shed from July 18th, 1895, to April 9th, 1896—this range of time exposing them to the highest temperature of an exceptionally hot summer, and the lowering of temperature incidental to a very cold winter.

Results of Gerdes' experiments

Of all the metals and alloys used, those which are known to resist ordinary oxidation in air remained perfectly unaffected, whilst the easily oxidisable metals suffered on the surface, but in no instance was it possible to trace any acetylene compound; and no explosion could be produced by either heating or hammering, whilst further experiments with acetylene, ammonia and water showed clearly that such corrosion as had taken place by the simultaneous action of ammonia-gas and acetylene was due exclusively to the action of the former gas, and no explosive compounds were formed.

Bullier's experiments on the formation of explosive compounds of Acetylene and Copper

If acetylene be passed through an ammoniacal solution of cuprous chloride, copper acetylene is formed, and when dry this explodes with great violence, when struck or when heated; and independent observations made by M. Bullier[1] showed that, in order to obtain this explosive compound of copper and acetylene, it was necessary that the gas should come in contact with a sub-salt of the metal in the presence of excess of ammonia.

The action of liquid Acetylene on copper

Pictet has claimed that liquid acetylene prepared by his process does not act upon copper or copper alloys, but Feischmann, who worked for a couple of years with liquid acetylene, denies this.

Grittner[2] has criticized Gerdes' conclusions, and

[1] *L'Electrochimie*, June, 1895.
[2] *Zeit. f. Calc. and Acet.*, 3. 106.

points out that if absolutely pure acetylene be allowed to pass through an ammoniacal solution of copper sulphate, no change takes place. If in this solution a clean piece of copper wire or a copper sheet be dipped, red acetylene-copper is formed directly. This proves that metallic copper reduces the cupric compound to cuprous compound. If the experiment be continued, the copper-acetylene falls off from the piece of copper and swims in the liquid. If the copper sheet is carefully washed, and, after drying, heated, the copper-acetylene on it explodes. The statement that acetylene in presence of ammonia gives no explosive compound is therefore wrong. If it were correct, no explanation could be found for the existence of copper-acetylene in copper gas-pipes.

The action of Acetylene on ammoniacal solutions of cupric salts in the presence of metallic copper

Grittner also allowed commercial acetylene from the acetylene works at Palolo to pass for months through a pipe containing copper gauze which turned black. The gauze emits sparks on heating, and, acted on by hydrochloric acid, gives a gas which yields with acidulated silver nitrate a white precipitate, which explodes on heating or striking with a hammer.

The action of commercial Acetylene on copper

He also tried if pure but moist acetylene acted on copper, and found that it did, whilst further experiments showed that pure dry acetylene did not even change the colour of copper when passed over it for 72 hours at the rate of 90 litres per hour.

The part played by moisture in the action

Grittner further tried the action of commercial acetylene on different copper alloys. The composition of the alloys taken was,—

The action of commercial Acetylene on copper alloys

	Brass.	Tombac.	Alpaca.	Britannia metal.
Copper	64·66	74·46	64·44	51·70
Tin		4·64		48·30
Lead	0·98	traces		
Zinc	34·16	20·67	16·33	
Nickel			18·79	

Strips of these alloys were placed in a glass tube

The method of experiment

attached to the gas-pipes leading from the works, and the acetylene flowed over them for three months continuously; it was found that the brass and tombac were acted upon, and yielded the explosive acetylene compound, but that the other alloys were unchanged. Further experiments prove that the presence of ammonia promotes the formation of the explosive compound, and Grittner finally concludes that,—

Grittner's conclusions

1 The copper-acetylene compound is always formed if impure acetylene is allowed to pass through neutral or ammoniacal copper solutions. In acidulated copper solutions a yellowish red precipitate is formed, containing no copper-acetylene.

2 Dry acetylene free from ammonia but containing the other impurities acts on copper and its alloys, as well as the moist and impure gas, and gives the explosive compound.

3 The pure and dry gas does not act upon copper and its alloys, though the possibility exists that after a long time the explosive compound will be formed under these conditions.

The toxic action of Acetylene

Acetylene used to be considered a highly poisonous gas, the researches of Bistrow and Liebreich[1] having apparently shown that it acted upon the blood in the same way that carbon monoxide did to form a stable compound. Experiments upon the toxic action of gases, however, are open to considerable error, partly depending upon the method by which the gas has been prepared, and which will affect its purity; and partly upon the nature of the animals upon which the experiments are tried, rabbits and other rodents resisting the action of gaseous poisons like carbon monoxide far better than carnivorous animals, such as dogs; and it is impossible to argue from the action of the gas upon the one what the action will be upon the other, whilst it has not yet been made clear that the action upon

Bistrow and Liebreich's experiments

[1] *Berl. Ber.*, 1867, 1, 220.

either is a very safe index as to the action of the gas upon man.

In 1895 Frank and Weyl[1] showed that warm-blooded animals can live for some time in an atmosphere containing 9 per cent. of acetylene without apparent injury, whilst Grehant[2] found that a mixture of 20 vols. of acetylene prepared from calcic carbide, 20·8 vols. of oxygen, and 59·2 vols. of nitrogen, was breathed by a dog for thirty-five minutes without any marked disturbance. With 40 vols. of acetylene, the proportion of oxygen remaining the same, a dog died in less than an hour, owing to failure of the heart's action, and 100 cc. of blood contained 20 cc. of acetylene. With 79 vols. of acetylene and 21 vols. of oxygen, the poisonous effects were still more strongly marked. It follows that acetylene may be fatally poisonous when present in proportions as high as 40 per cent. by volume.

Grehant's experiments show that a large percentage of Acetylene is necessary to be dangerously poisonous

A mixture of coal-gas with air and oxygen, containing 20·8 per cent. of the latter and 1 per cent. of carbonic oxide, was nearly fatal to a dog after it had been breathed for about ten minutes, and 100 cc. of the dog's blood contained 27 cc. of carbonic oxide. It follows that acetylene is much less poisonous than ordinary coal-gas.

Acetylene less poisonous than coal-gas

Berthelot,[3] in some experiments made many years ago, in conjunction with Claude Bernard, found that acetylene, when present to the extent of a few per cents. by volume, is without injurious effects on birds. The poisonous properties often attributed to this gas, as prepared by the older methods, are probably due to the presence of carbonic oxide or hydrogen cyanide.

The poisonous properties found in the older experiments due to impurities

Moissan[4] finds that when acetylene is prepared from pure calcium carbide, and is purified by being liquefied, it has a very pleasant etherial odour. If, however, the

[1] *Zeitsch. Ver. Deutsch. Ing.*, 1895. [2] *Compt. Rend.*, 121, 564. [3] *Ibid.*, 566. [4] *Ibid.*, 566.

calcium carbide has been prepared from coal and impure lime, it may contain calcium sulphide and phosphide, and the acetylene prepared from it then has a very disagreeable odour.

Action of Acetylene on blood

Brociner[1] also made experiments which show that 100 vols. of blood dissolve about 80 vols. of acetylene; the solution shows no characteristic spectrum, and is reduced by ammonium hydrosulphide as readily as ordinary arterial blood. In a vacuum part of the acetylene is evolved at the ordinary temperature, and part at 60°. If the blood is allowed to putrefy the volume of acetylene given off at the ordinary temperature remains practically the same, but the quantity liberated at 60° decreases as putrefaction advances. If any compound of acetylene and hæmoglobin is formed, it is very unstable, and is not analogous to carboxyhæmoglobin. The poisonous action of acetylene is very feeble, and animals can breathe large quantities of the gas for several hours without injurious effect, provided the proportion of oxygen is kept up to the normal amount, and the products of respiration are not allowed to accumulate.

The poisonous properties of Acetylene very feeble

Rosemann found that[2] acetylene prepared from calcium carbide contained hydrogen phosphide and sulphide. This impure product is less poisonous than coal-gas. It produces no change in the blood; it causes sleepiness, the respiration becoming slow, deep, and finally dyspnœic. Some animals vomited. Its action appears to be on the nervous system.

The action of Acetylene chiefly on the nervous system

Oliver, in a paper published in the *British Medical Journal*, 1898, thus describes the physiological effects of acetylene upon a rabbit:—

"When somnolence has been induced, and asphyxia not pushed too far, the rabbit, when removed from the bell-jar and placed in ordinary atmospheric air, begins to move about in a few seconds in as lively a manner

[1] *Compt. Rend.*, 121, 773. [2] *Chem. Centr.*, 1895, 11, 998.

as if it had not been interfered with, there being neither weakness nor paralysis of its limbs. In a word, a few inhalations of atmospheric air are sufficient to restore to the animal all its faculties.

The symptoms of Acetylene poisoning

"Should the inhalation have been pushed further, and the animal have been very deeply asphyxiated, death may ensue; cyanosis hitherto observed being rapidly replaced by extreme pallor. In the minor and easily recoverable stages of asphyxia the vascular tension is still maintained, and there is no difficulty in obtaining a drop of blood for examination; but when the deeper stages are reached, so extremely contracted are all the vessels that it is almost impossible to obtain even a trace of blood. When this stage has been reached recovery is very difficult. It is interesting at this point to mention that, when we examined the blood of a rabbit at different stages of intoxication from acetylene, and especially in the deepest asphyxia, this fluid on spectroscopic examination always exhibited two well-marked bands of oxyhæmoglobin; also that, unlike the blood in coal-gas poisoning, although resembling it in the cherry-red colour which it presented, it was readily reduced on the application of ammonium suphide and gentle heat. To that extent, therefore, if the asphyxia caused by the acetylene is not too profound—and under ordinary domestic circumstances it would not be a pure acetylene atmosphere that would be inhaled by an individual, but one mixed with a large proportion of ordinary air—the danger to life seems to be less than it would be in coal-gas poisoning, and the prospect of recovery by removal to atmospheric air greater. Death may supervene, however, if the inhalation has been lengthened and atmospheric air excluded."

Appearance of the blood

Part II

CHAPTER V

THE ELECTRIC FURNACE

And its Application to the Manufacture of Calcium Carbide

Acetylene becomes a commercial possibility

THE commercial possibility of utilising acetylene for illuminating purposes depends upon its cheap production, as all the time the gas had to be made by such processes as those described in the early portions of Chapter II., it was a laborious operation to obtain even a few cubic feet of the gas, and an impossibility to get it in sufficient quantity for illuminating purposes.

When, however, it was discovered that calcium carbide could be formed by the direct combination of calcium with carbon, it at once became apparent that this might lead to important results, and that the ease with which acetylene could be developed from calcium carbide by the action of water would make its production one of the simplest gas processes known. It was not, however, until the importance of the electric furnace as an agent for producing intense temperatures became fully realised that cheap carbide could be obtained.

Commercial Carbide

The chemical processes involved in making carbide are two. First, the reduction of the lime or calcium oxide to calcium, and, second, the combination of the calcium with carbon to form the carbide; and it is for the first part of the operation that the intense temperature of the arc is necessary.

The causes which lead to chemical decomposition

In order to decompose any compound an amount of energy equivalent to that produced when it was built up has to be employed, and in actions of this kind the form of energy used is either chemical, thermal, or a combination of the two. When the oxides of the alkaline earths are heated with potassium, the latter body has a tendency to remove the oxygen if the temperature be sufficiently high, and if carbon be present the nascent metal at the moment of its liberation combines with it, forming the carbide. That this is the case is clearly shown by the formation of carbide in the residues left during the manufacture of potassium, and by the researches of Wohler, Travers, and Maquenne, who all produced carbides by making a mixture of the oxides of which the carbide was required with another metal having an affinity for oxygen, which, if the fusing point of the mass is attained, takes the oxygen from the oxide and sets it free in a condition favourable for its combination with carbon.

The formation of Carbides

The energy necessary for the reduction of the oxides of the alkaline earths

In order to do this the heat necessary is not so enormous, as a large amount of the energy employed is chemical; but if the same action is to be brought about by the smaller amount of chemical energy, due to the affinity of carbon for oxygen, such temperatures as those obtained in the electric furnace have to be employed.

The importance of the electric furnace

The formation of calcium carbide is by no means the only problem which the introduction of electricity, as a method for obtaining high temperatures, has helped to solve; and the re-introduction of the electric furnace in 1879, by Siemens, will, in all probability, be looked back to in the future as marking not only the introduction of a process capable of cheapening the production of aluminium and such bodies as calcium carbide, but also as being the starting-point of many processes which, without its aid, would have been impossible.

In June, 1800, Volta communicated the discovery of the pile which bears his name to Sir Joseph Banks, the then President of the Royal Society, and in the fall of the same year Humphry Davy published in *Nicholson's Journal* an account of experiments made with it, and pointed out that, with his roughly-constructed pile, he was able to produce sparks that were visible in daylight, and that these sparks could be obtained between terminals of different metals, but varied considerably in brightness according to the material used, well-burnt charcoal giving the best results. He also found that to render the charcoal a good conductor it must be hard and so well burned as to be almost metallic in lustre, the best carbon being produced by quenching it in quicksilver.

Volta's discovery of the pile

Sir Humphry Davy shows the heat and light developed in the electric arc

Pepys also, who was a friend of Sir Humphry Davy, heated diamond dust between two iron terminals by means of the current, and found that whilst the diamond dust disappeared the iron was converted by cementation into steel.

Pepys makes steel by cementation in the arc

This century has been rich in researches upon the electric arc, owing to its introduction for purposes of illumination, but there is undoubtedly much yet to be learnt as to many of its properties.

When a current is flowing through a wire, the breaking of the wire causes a leaping of the current between the fractured ends as long as they are within a distance sufficiently small as compared with the strength of the current, and with a powerful current this disruptive discharge may be maintained continuously, emitting a dazzling light, though the best results are obtained, as regards illuminating effect, if the ends of the wires be fitted with carbon pencils.

The formation of the electric arc

The light of the voltaic arc is due partly to the electric arc itself, partly to the incandescent carbon poles, and partly to the transport of small particles

The causes of light emitted by the arc

Influence of the carbon terminals used on the arc

of carbon from the positive to the negative pole. The softer and more friable the carbon is, the longer

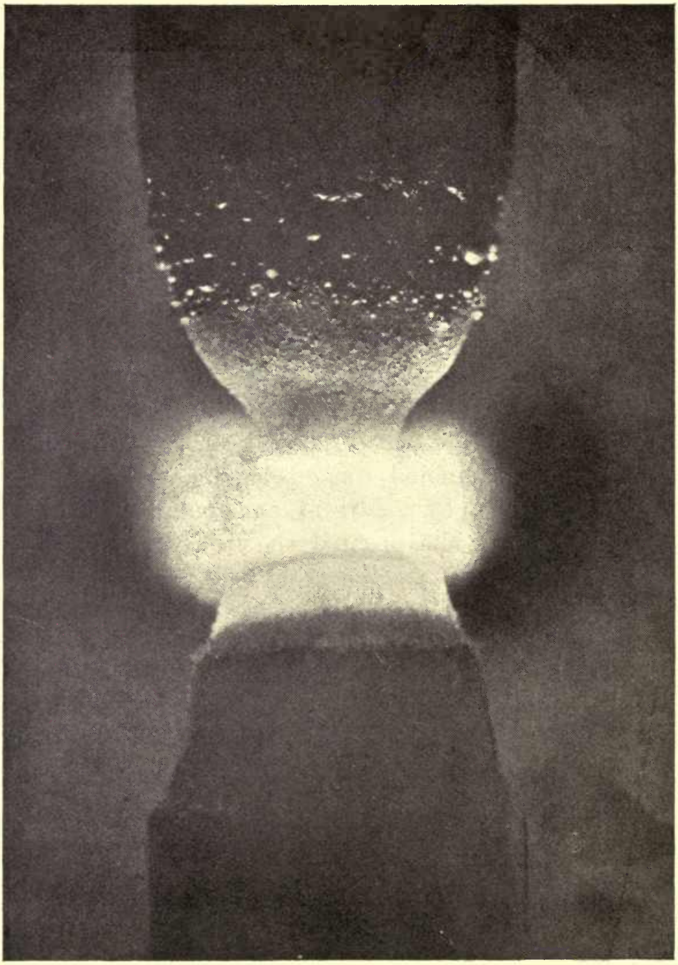


FIG. 23. THE ELECTRIC ARC.

is the arc which can be produced; but when light is the object of the arc the densest possible carbon is employed, in order to obviate the rapid wasting of

the positive pole. In starting such an arc the tips of the carbon pencils are first brought together, and are then drawn apart to such a distance that the arc passes freely between them. The tips become brilliantly white hot, and after burning for a few minutes it will be seen that the positive carbon is slightly flattened out, and that a small hollow crater has formed in it, and it is from this point that the largest amount of light is emitted. There is then a pale blue flame between the carbons, and the negative pencil takes a pointed form, becoming white hot, but not emitting either as much or as white a light as the positive pole.

Effect of the arc on the shape of the carbons

When the carbons are the right distance apart the arc burns with perfect silence, but when they are separated too far it has a tendency to roar and go out, whilst if they are brought too close together a hissing sound is noticed, and the negative tip shows a deposition on it of projections.

Action of the distance between the poles on the arc

The whiteness of the light emitted by the crater seems to be fairly constant, from which one would argue that it is always at an equal temperature, but the larger the current employed the larger the surface of the crater. This naturally suggests the idea that the apparent fixed temperature of the crater surface is the volatilising point of the carbon, and that it is evaporating off the positive carbon into the arc.

The temperature of the arc probably governed by the volatilising point of carbon

The experiments of Despretz show that just before the volatilisation of carbon takes place it becomes very soft, and that there is an incipient liquefaction going on a few degrees below the temperature of volatilisation, and Silvanus Thompson[1] advances the view that the physical state of the crater is such that the solid carbon is covered with a layer or film of liquid carbon just boiling or evaporating off.

The experiments of Despretz

Silvanus Thompson's theory as to the condition of the carbon in the arc

As the electric arc burns in the air, carbon dioxide

[1] *Jour. Soc. Arts*, 43, 951.

Gaseous products of the arc

carbon monoxide, oxides of nitrogen, hydrocyanic acid, cyanogen, and other gaseous compounds are produced, together with ozone, which give a distinct smell to the products escaping from the arc lamp, high voltages soon giving a noticeable odour, whilst with a normal arc produced at 40 or 50 volts little or no smell can be detected.

Temperature of the electric arc estimated by Becquerel

Rossetti deduces it from the radiation

Violle determines it by experiment

The temperature attained in the electric arc has been variously estimated, Becquerel, in 1860, giving 2,070–2,100° C. as being the probable temperature of an arc obtained from 80 Bunsen cells, whilst in 1879 Rossetti deduced the temperature of the arc from observations on the radiation, and came to the conclusion that the temperature of the positive crater approximated to 3,900° C. and that of the negative pole to about 3,150° C. Violle has attempted the calorimetric determination by providing his positive carbon with a small end piece, which became the crater of the arc and was allowed to burn away till quite thin, when it was knocked off into the calorimeter, and the amount of heat it gave out on cooling measured, and he finally came to the conclusion that the temperature of the arc is 3,500° C. Gray has also attempted the solving of the same problem, and states the temperature to be 3,400° C.; so that in all probability the temperature given by Violle is fairly accurate. Violle also found that, if he used zinc poles instead of carbon ones, he could raise the temperature of a piece of carbon held in the arc itself to a manifestly higher point than existed at either of the poles, the temperature of which was governed by the volatilisation of the metal.

Gray's determination of the temperature

The genesis of the electric furnace

Assuming that the temperature of the arc is really 3,500° C., it is evident that it gives a possibility of obtaining a temperature between 1,000 and 2,000° hotter than can be arrived at by any other means. As early as the forties attempts were made to utilise

the temperature of the arc for metallurgical purposes, and Napier, in 1845, produced an electric furnace, in which he hoped to reduce certain metals from their ores. This consisted of a lined plumbago crucible, into which a carbon electrode was introduced as the positive pole. Children also made similar experiments on a small scale.

Napier's furnace

In 1849 Despretz made what was practically a furnace of the same type, whilst in 1853 Pichon designed an electrical furnace for the reduction of ores, in which a mixture of the powdered mineral and ground up coke was allowed to fall between two sets of carbon

The Pichon furnace

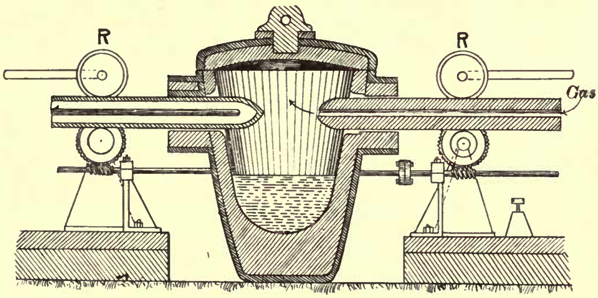


FIG. 24. SIEMENS FURNACE.

poles forming the electrodes, and was thus twice subjected to the influence of the arc.

Joule and Sir William Thompson also tried to utilise the temperature of the electrical discharge, but it was not until the seventies that any practical success attended the efforts to introduce an electrical furnace.

In 1874 Werdermann suggested electrical fusion for the more refractory minerals, and in 1879 Siemens, Faure, Fox, Lentin, and Bertin were all working at the subject, with the result that Sir William Siemens, in 1879, took out a patent for an arc furnace, Fig. 24, which was exhibited in 1881. It consisted essentially of

The electric furnace assumes a practical form

Siemens electric furnace

a crucible of refractory and non-conducting material, through the sides of which were introduced the two carbon poles between which the arc was formed. The electrodes were either both of carbon, or the positive pole of carbon and the negative of metal, kept cool by the circulation of water, whilst as the positive pole was consumed the electrodes were drawn together by screws.

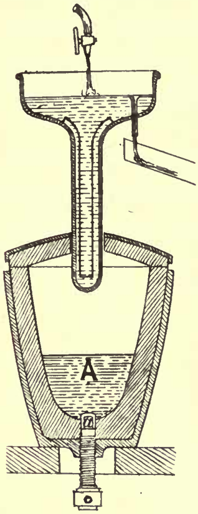


Fig. 25. Siemens 2.

The second modification of the Siemens furnace, Fig. 25, which could only be employed when the material to be acted upon was a good conductor of electricity, consisted in bringing the current into the crucible by a metal screw, which transmitted the current to the substance A, whilst the negative pole was brought down on its surface from above. The substance to be acted upon was in this way made the positive terminal, whilst the negative pole above it was kept cool by the circulation of water.

Clerc furnace

Another furnace, also exhibited in 1881, was due to Clerc, Fig. 26, and consisted of a block of magnesia or calcic carbonate, in which a cavity was formed, and the two carbons brought into it horizontally through holes in the sides.

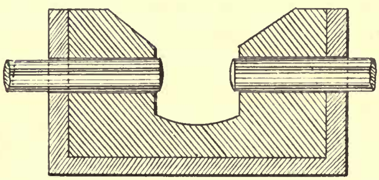


Fig. 26. Clerc Furnace.

Cowles furnaces

The most important electric furnace, as far as marking the introduction of electric furnaces for commercial purposes, was undoubtedly that patented in 1885 by Alfred and Eugene

Cowles, and used by them in their work on aluminium. The charge to be treated was powdered and mixed with retort carbon, the whole being then brought to

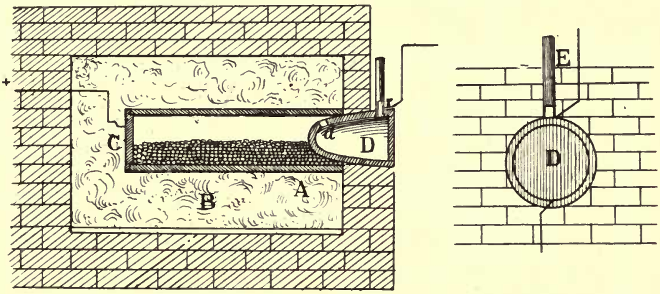


FIG. 27. COWLES FURNACE.

Cowles retort furnace

incandescence by means of the current. The furnace consisted of a cylinder A, Fig. 27, made of some non-conducting refractory material, surrounded by a mass of charcoal or other bad conductor of heat. The positive electrode was a plate of carbon C, which also served to close the end of the retort, the other end being sealed by a graphite crucible D, which acted as the negative electrode.

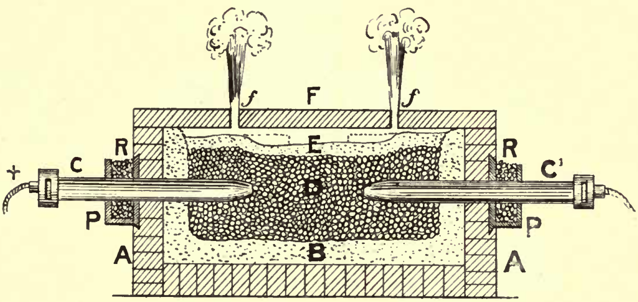


FIG. 28. COWLES FURNACE.

Cowles furnace, with

Another form of furnace, Fig. 28, was patented in 1886 by Messrs. Cowles, in which the carbon poles CC[1]

horizontal poles

were placed horizontally, and the charge D was packed around them, the poles at the start being close together, but being gradually withdrawn as the electric resistance of the furnace fell. This furnace was further improved by the addition of an ammeter, and resistance placed in the circuit in order that the process might be well under control.

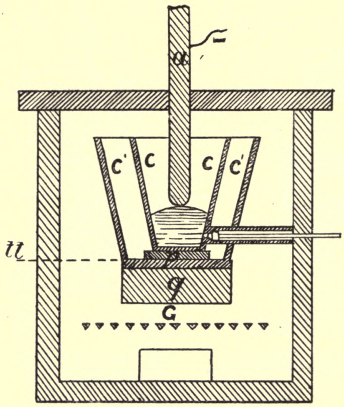


FIG. 29. BERNARD FURNACE.

Bernard furnace

In 1887, Bernard Freres patented a furnace, Fig. 29, in which a crucible of refractory material c^1, resting on a carbon plate *q* which formed the positive pole, contained a carbon crucible c in which the charge was

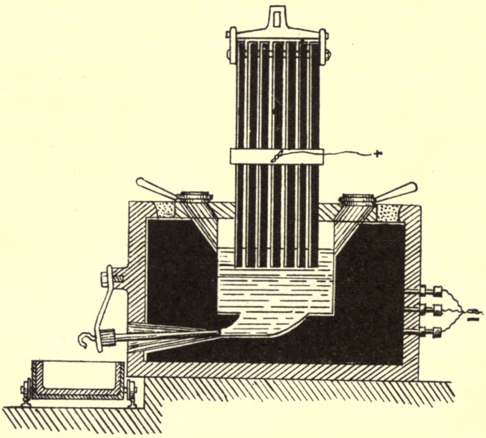


FIG. 30. HEROULT FURNACE.

placed. The negative electrode consisted of a rod of carbon *a* brought down on to the top of the charge.

The two crucibles were first heated by an external furnace, and when the requisite temperature was attained, the final heating was accomplished by means of the electric current.

Heroult, in 1887, devised a furnace for the manufacture of aluminium, in which an inner crucible, containing the charge, was placed inside another crucible made of carbon, the two being capable of being heated by a furnace. The positive pole was

Heroult furnace

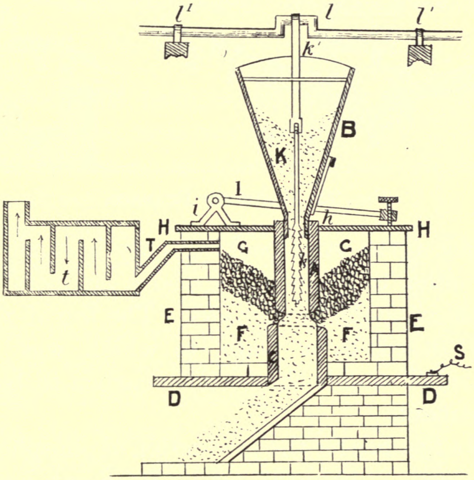


FIG. 31. COWLES CONTINUOUS FURNACE.

brought centrally into the inner crucible, whilst the negative electrode was formed by the crucible itself.

Cowles continuous furnace

In 1887, also, Messrs. Cowles introduced an electric furnace, in which the charge could be fed continuously. This was composed of a vertical carbon tube forming a positive pole, to the upper end of which was fixed a feed hopper. The negative pole was also a carbon tube slightly larger than, and placed a short way below, the positive pole, and resting on a plate fixed at the bottom of the furnace. The space between the electrodes and the walls of the furnace was packed

to the top of the negative carbon with a mixture of charcoal or lime and retort carbon, whilst round the

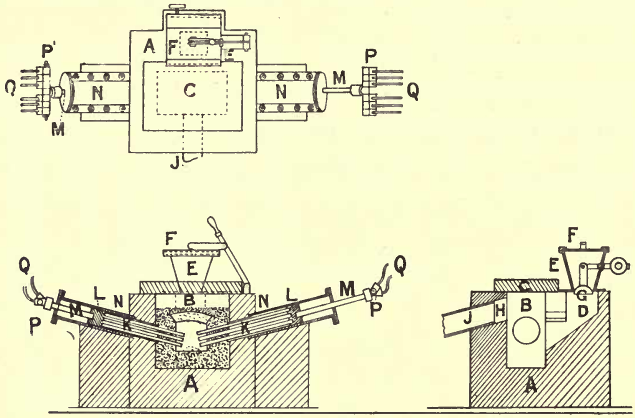


Fig. 32. Readman Furnace.

arc was placed the same packing, only in much coarser grain in order to allow any gaseous products to pass through it into the condensers. The top of the furnace was closed by a plate, to which was fixed a pivoted arm to enable the positive carbon to be moved for adjustment.

Readman furnace

Reuleaux and Crompton pre-heating furnaces

In 1888 a furnace for the production of phosphorus was brought out by Readman, and in the same year Reuleaux devised an electric cupola, the charge being heated before it was subjected to the arc.

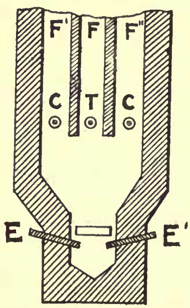


Fig. 33.
Reuleaux Furnace.

Crompton, too, in 1888, patented a furnace, Fig. 34, in which the material could be heated by external agencies before the current was switched on.

Kiliani furnace

In the following year Kiliani devised an arrangement, in which the positive carbon produced a rocking and rotating movement in the bath which formed

the negative pole; thus the formation of a hard crust

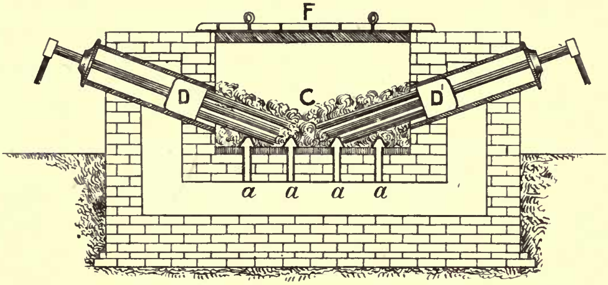


FIG. 34. CROMPTON FURNACE.

on the top of the bath, which prevented the addition of fresh material, was avoided (Fig. 35).

Parker's multiple pole furnace

Parker, in the same year, 1889, employed two rows of electrodes, placed horizontally opposite each other, the carbons being in contact before the charge was introduced, and then separated.

Willson's furnace, with hollow pole

In 1890 Willson patented a furnace, the object of which was to diminish the wear and tear of the anode in mixed electric furnaces. In order to accomplish this he formed his anode of a car-

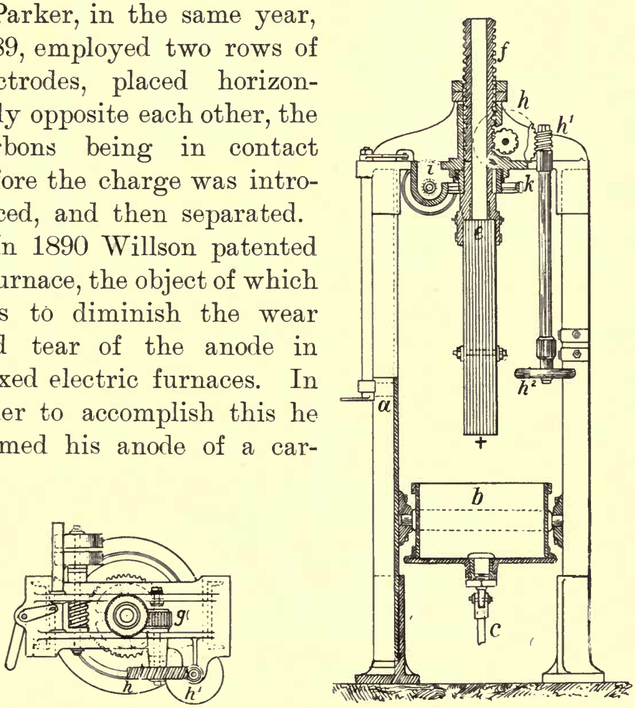


FIG. 35. KILIANI FURNACE

bon tube, through which was passed hydrogen, coal gas, or some other hydrocarbon gas.

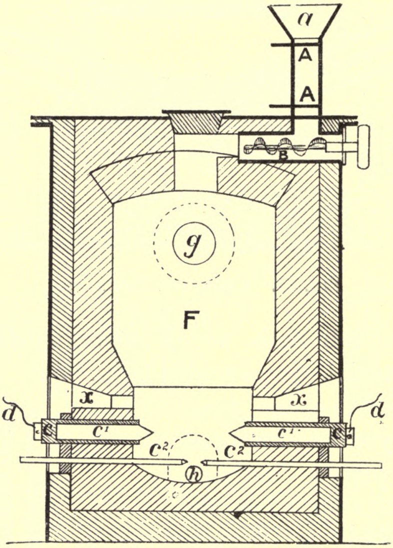


FIG. 36. PARKER FURNACE.

Schneller furnace

Schneller and Astfalck employed high-tension currents in their furnace, this being necessary in order

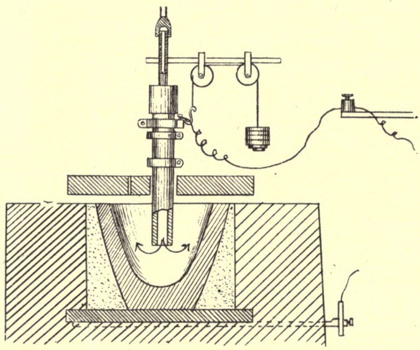


FIG. 37. WILLSON'S FURNACE.

to overcome the resistance of the charge, and also to

help the reduction effected by hydrogen or some suitable hydrocarbon.

In the Laval furnace, patented in 1892, an alternating current was employed, which was passed through a material of low conductivity in a molten condition, thus bringing it to a very high temperature. The furnace was divided lengthways by a bridge of refractory material, the poles being laid at the bottom of the furnace, whilst the current passed through the molten electrolyte over the bridge of refractory material. The charge was dropped in through an

Laval furnace for alternating currents

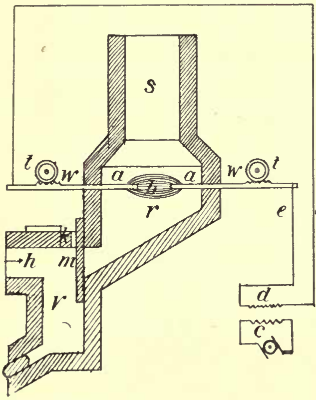


FIG. 38. SCHNELLER FURNACE.

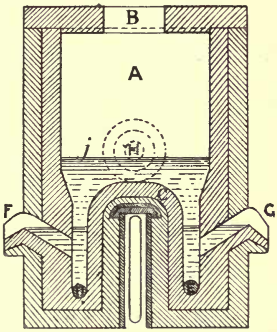


FIG. 39. LAVAL FURNACE.

opening in the top of the furnace, whilst the melted metal escaped through outlet pipes below the surface of the electrolyte.

Girard and Street, in 1893, took out a patent for a continuous feed furnace. The crucible containing the charge was placed inside two carbon tubes which formed the electrodes, and between which the arc was struck. Upon the arc was brought to bear a magnetic field by winding the outside of the furnace with coils traversed by an electric current, under the influence of which the arc was caused to rotate slowly

Girard and Street's continuous feed furnace

in a horizontal plane, thus ensuring an even distribution of heat.

Moissan's researches

Undoubtedly, the most important experimental work performed with the electric furnace consists of the beautiful researches made by Moissan, for which he devised several modifications of the earlier furnaces, in order to fit them for the special purposes he had in view. His work, however, was of a purely scientific character, and the furnaces only fitted for scientific research on a laboratory scale. The description of the various forms he employed is best given in his own words.

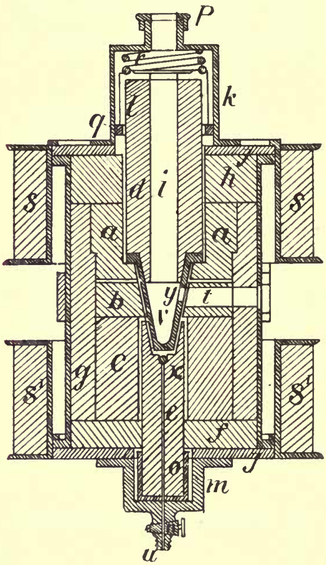


Fig. 40. Girard Furnace.

Construction of Moissan's experimental furnace

"Our first model of the electric furnace, brought before the Académie des Sciences in December, 1892, consisted of two bricks of quicklime carefully prepared and placed one on top of the other. The lower brick contained a longitudinal groove to receive the two electrodes, and situated in the centre was a small cavity forming the crucible. This cavity might vary in size, and contained a bed some centimetres in depth of the substance to be acted upon by the heat of the arc, or a small crucible of carbon containing the substance to be treated could be placed there.

Arrangement of the electrodes

"The upper brick was slightly hollowed out in the part just above the arc. As the intense heat of the current soon melted the surface of the lime, giving it, at the same time, a beautiful polish, a dome was

obtained in this way which reflected all the heat on to the small cavity which contained the crucible. The electrodes were fastened to two movable supports, or, better still, upon two sliding pillars.

"The difference between this electric furnace and all previous ones is that the substance under examination does not come in direct contact with the electric arc—that is to say, with the vapour from the carbon.

"The apparatus is a reverberatory electric furnace with movable electrodes. The last point is of impor-

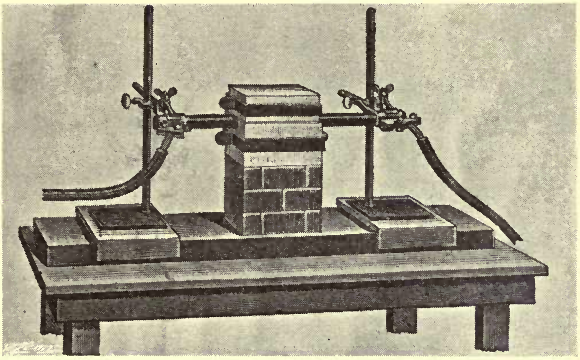


Fig. 41. Moissan's Furnace.

tance, as the mobility of the electrodes affords great facility in establishing the arc, in extending or diminishing it at will, and, in fact, greatly simplifies the carrying out of the experiment.

"In our first researches we employed a small Gramme machine worked by a gas engine of 4 H.P. As a rule, the current traversing the furnace indicated 35 to 40 ampères and 55 volts, whilst the lower lime brick was 16 cm. to 18 cm. in length, 15 cm. in breadth, and 8 cm. in thickness. The upper brick, which formed the cover, presented the same surface with a thickness of 5 to 6 cm. This size of apparatus

Current used, and dimensions of the furnace

is sufficient for a current of 100 to 125 ampères and 50 to 60 volts.

"When using the furnace for more powerful currents it is as well to enlarge the three dimensions of the furnace by 2 or 3 cm. With a furnace of 22 to 25 cm. in length, a current of 450 ampères and 75 volts can quite well be employed. The lime used in these researches was slightly hydraulic, obtained from the Parisian basin, and called *du banc vert.* It is shaped or turned with ease, and is the same as was approved by Deville and Debray for their fusion of platinum on a small scale.

Lime used

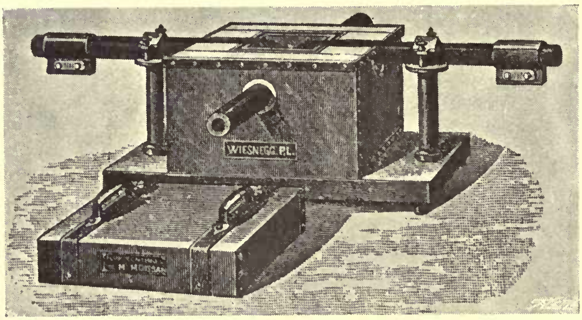


FIG. 42. MODIFIED MOISSAN FURNACE.

The carbon poles

"The electrodes were formed from carbon rods as free as possible from mineral matters; some difficulty was at first experienced in obtaining them pure. They should be made of retort carbon reduced to powder, and selected from the top of the retort. This powdered carbon is treated with acids, to free it as far as possible from the iron it contains; it is then washed and heated, and finally made into a stiff paste by means of tar. The rods are formed by pressure, which ought to be very high and regular; they are then dried with care and heated to a high temperature. The rods must be tested to see if they contain

Manufacture of the carbons

boric acid or silicates, which are sometimes added to facilitate their manufacture, and all rods containing these substances should be rejected, as well as those containing more than 1 per cent. of ash.

Dimensions of the electrodes used

"For the smaller furnaces we employed electrodes 20 cm. in length and 12 mm. in diameter. With a current of 120 ampères at 50 volts, we employed rods 40 cm. in length and 15 to 18 mm. in diameter. When using a machine of 40 to 45 H.P., electrodes 40 cm. in length and 27 mm. in diameter were employed.

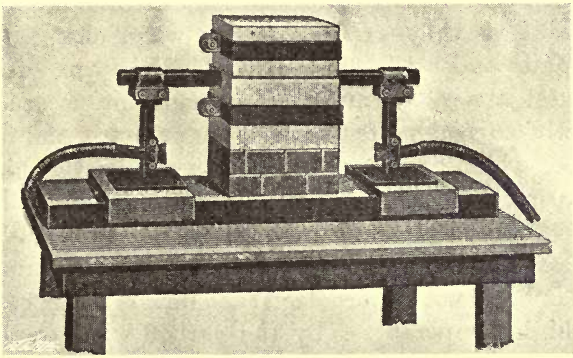


FIG. 43. MOISSAN FURNACE.

Influence of using pointed carbons on the ease with which the arc can be struck

"The extremities of the electrodes between which the arc is produced were shaped into finely pointed cones. This precaution is important, especially with small currents, as if not taken it is difficult to relight the arc if it happen to be extinguished at the commencement of an experiment. With 350 ampères and 60 volts we employed only one pointed electrode, the other being left smooth.

"All difficulty disappears once the furnace has become hot, and is filled with vapours which are good conductors, and which allow of the arc being relighted with the greatest ease. The wires which convey the current are joined to the carbon rods by

means of copper clamps fixed by screw nuts. This arrangement has already been employed for some time in the use of high-tension currents.

"During the first period of our researches we employed retort carbon crucibles, which were made circular and in one piece. These crucibles were cylindrical, and had two holes, one on either side, sufficiently large to allow of the easy entrance of the electrodes. With machines of 4 to 8 H.P. we employed crucibles 3 cm. in external diameter and 2 cm. internal diameter. Their height was 4 cm. and the hole 1·5 cm. These retort carbon crucibles are inconvenient, as they expand greatly when changed into graphite under the intense heat of the arc. At our request several manufacturers made for us crucibles of stiff carbon paste moulded by pressure, and in one piece, which have kept their shape under the highest temperatures. A circular space must be allowed round the crucible in order that the heat rays reflected from the dome may completely surround it.

Carbon crucibles used in Moissan's researches

"It must not be forgotten that lime is easily reduced at high temperatures by the carbon with formation of calcium carbide.[1] When a crucible is to be heated in this lime furnace care must be taken to have a bed of magnesia at the bottom of the cavity. Magnesia is, in fact, the only oxide we have ever encountered which is not reduced by carbon. When the experiment lasts long enough the magnesia may run down with the already liquid lime in the furnace, and may even volatilise, but never forms a carbide."

Magnesia as a refractory material in electric furnaces

Moissan also designed several other forms of this furnace for specific purposes, but they were all of the same type, and of a purely scientific and experimental character (Figs. 42 and 43).

Electric furnaces may be divided into two classes:—

Electric furnaces may be

I. Those in which the substance to be heated is

[1] *Compt. Rend.*, cxvii, 501.

placed in the path of the electric arc, or is made to form one or both poles for the formation of the arc, as in the furnaces already mentioned.

classed under two heads

II. Those in which the heat is generated by offering resistance to the flow of the current, as when a piece of thin platinum wire is heated to incandescence by making it the link between two copper wires of greater diameter through which the current is passing.

1. Arc furnaces

2. Resistance furnaces

The furnace of Despretz was the earliest of the second class, as he took a tube made of sugar charcoal, 7 mm. in diameter and 23 in length, in which he placed the substance to be heated, and closed the ends of the

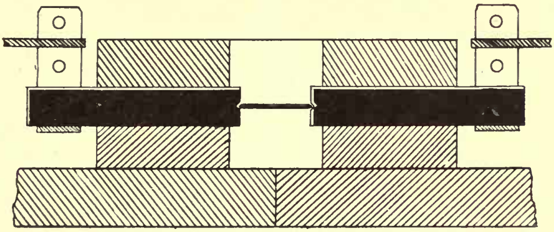


FIG. 44. BORCHER'S FURNACE.

tubes with carbon poles; whilst the modern type of this class of furnace may be taken as Borcher's experimental furnace, described in 1891, in which he reduced many of the metallic oxides.

Borcher's furnace

The body of the furnace is made of fire-clay, standing on a bed of refractory firebricks. In the centre is a cavity, in which the mixture to be heated is placed; the sides of the furnace are pierced by holes, through which pass the conducting carbons, the poles being joined in the centre of the mixture by a narrow rod of carbon, which, offering resistance to the passage of the current, becomes intensely heated.

A few attempts have been made to introduce furnaces of this type for the manufacture of calcium

Resistance furnaces proposed for

making Calcium Carbide

carbide, King & Wyatt, in 1895, patenting in the United States a furnace consisting of an open hearth, in which one carbon rose from below and the other pole was suspended from above, the two being connected by a thin carbon rod, the mixture of lime and carbon being heaped around them, and the ingot of carbide forming in the centre of the mass, so that the

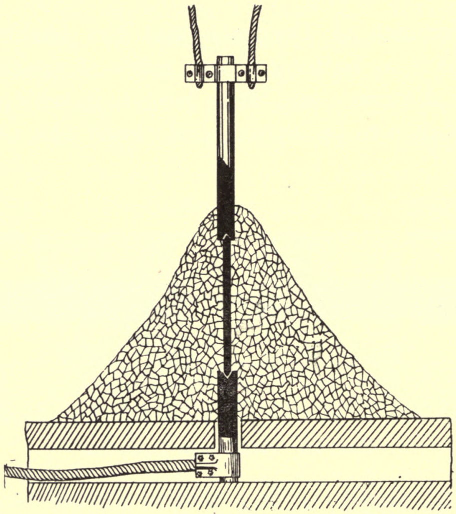


FIG. 45. KING'S FURNACE.

excess of mixture really formed the sides of the furnace.

Maxim-Graham resistance furnace

Hudson Maxim also designed a furnace on this principle. The mixture of lime and carbon is fed into troughs, the sides of which are made of magnesia bricks, behind which is a tight packing of broken charcoal in connection with the leads from the dynamo, one side of the trough receiving the positive and the other the negative current. Through the broken carbon he passes thin rods of dense carbon, which pass through the mixture and make a connec-

tion between the two poles, the broken carbon acting as a contact maker. He claims that, as these rods become incandescent, carbide forms around them, and that, when the rods have fused, the carbide continues to carry the current, and forms more carbide on its surface, and that these rods or ingots of carbide are then picked out from the trough and new material and carbon rods introduced.

Arrangement of the furnace

This furnace, generally known as the "Maxim-Graham," was tried at Trowbridge in 1897, and it was claimed to be possible to make with it from 0·4 to 0·5 lb. of carbide per E.H.P. of 81 per cent. carbide per hour. This type of furnace, however, has never been adopted on more than an experimental scale, and it will be well to now trace the growth of the carbide industry and the evolution of the forms of apparatus which are in use on a manufacturing scale at the present time.

The Trowbridge experiment

America, the birthplace of commercial carbide, naturally produced the earliest forms of carbide furnace, which were all of the arc type, and produced the compound in the form of ingots.

American furnaces for making ingots of Calcium Carbide

First and foremost amongst these stands the furnace employed by Willson at Spray, in which the earliest commercial carbide was made. The following description of the plant is taken from the report to the *Progressive Age* by Professor Houston and Drs. Kenelly and Kinnicutt upon Willson's process:

The Willson Carbide furnaces at Spray

"The plant consists essentially of a pair of electric furnaces for producing the carbide, electric generators for supplying the current, a turbine for driving the electric generators, and suitable apparatus for pulverising and mixing the coke and lime required to charge the furnaces.

The machinery for generating the power

"The water motor is a horizontal twin Leffel turbine wheel, 30 inches in diameter, and rated as capable under 28 feet fall of generating 300 H.P. at 206 revo-

Willson's Works at Spray

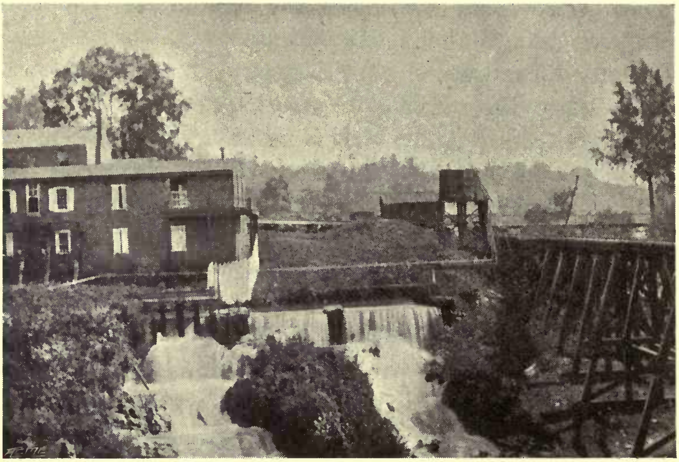


Fig. 46. Willson's Works at Spray.

lutions per minute and $\frac{3}{4}$ gate opening. The gate opening is controlled by hand.

"The turbine is belted directly by tandem belts

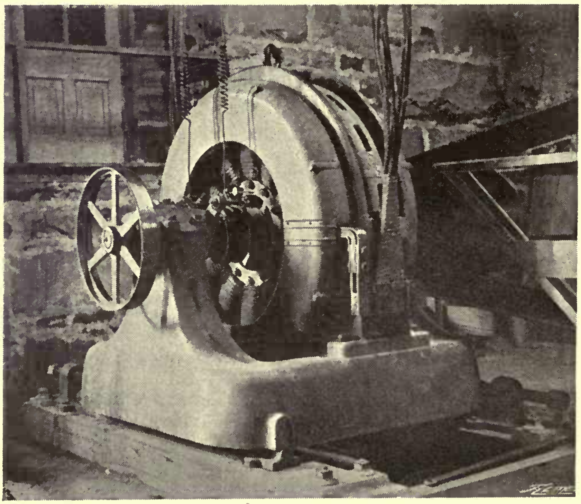


Fig. 47. Willson's Dynamo.

to two Thomson-Houston alternators of the 14 pole 120 kw. 1,070 revolutions per minute type, giving a maximum effective pressure of 1,155 volts at full load. Each alternator is excited by a standard Thomson-Houston exciter of the 110 volt 18 ampères 2,500 revolutions per minute type. Both exciters are run by tandem belts from an outboard pulley on one alternator shaft. The terminals of the alternator are connected to a switchboard supplied with primary volt meters, ammeters, and switches. **Turbine and Dynamos**

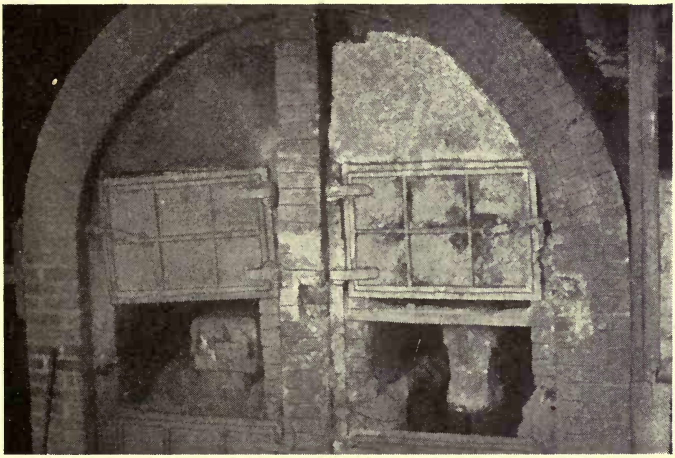


FIG. 48. THE SPRAY FURNACES.

"The mains from the switchboard run to a group of sixteen alternating current transformers, eight to each alternator, representing a total capacity of 240 kw. or 321·8 H.P. These transformers are employed to lower the pressure from 1,000 volts at the alternator terminals to 100 volts at the furnace terminals. They are of the No. 4 15,000 watt 60 cycle Thomson-Houston type. The secondary coils of these transformers supply in parallel two bundles of copper cables leading to the furnaces, which are situated **Transformers**

within a few feet of the switchboard. Each cable is about ¼ inch in diameter, and is composed of 120 separate wires. There are sixteen cables to each furnace—eight to the upper and eight to the lower electrode.

Electric furnaces used at Spray

Construction of the Spray furnaces

"There are two open electric furnaces placed side by side in one brick structure. The side and partition walls are of ordinary brick, whilst the front is open, but partly covered by cast-iron doors. The floor space in each furnace is 3 ft. × 2 ft. 6 in., and at a height

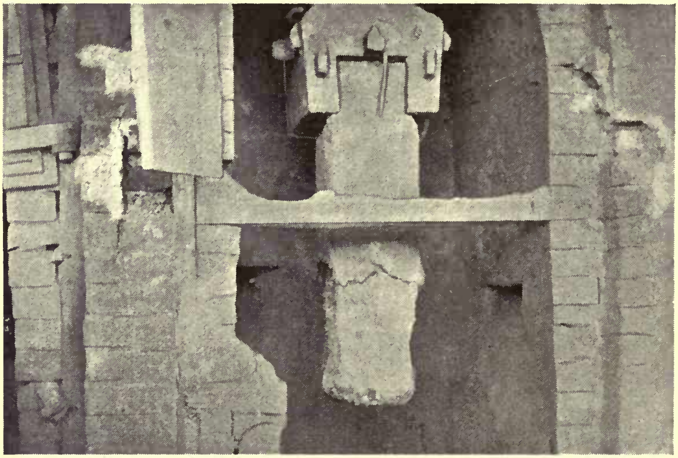


Fig. 49. Carbon and Holder.

of about 8 feet they rise into a single short chimney, which serves to carry off the gases evolved during the operation of the furnaces.

"At the base of the furnaces is placed a heavy iron plate about 6 ft. long by 2½ ft. wide, and 1 to 2 inches thick. On this bed-plate rest two carbon plates, 3 ft. by 2½ feet, and 6 to 8 inches thick, one in each furnace. These carbon base plates in connection with the iron plate form the lower electrodes. They are repaired from time to time with carbon left over

from partly-consumed upper electrodes. Their renewal thus involves no extra expense in materials.

The electrodes used

"The upper electrode for each furnace is a heavy carbon block 12 × 8 inches in cross section, and 36 inches long. It is composed of six carbons laid side by side, each 4 × 4 inches, 36 inches long, and weighing approximately 30 lbs. The electrode is protected by a casing of $\frac{3}{32}$ inch sheet iron. The interstices between the casing and the carbons is filled with a hot mixture of pulverised coke and pitch, so that the electrode becomes practically a solid mass of carbon in intimate contact with an iron shell. The electrode is clamped vertically in a metal holder supported by a vertical copper rod, 3 × 3 inches, passing through the roof of the furnace to a chain running over a pulley to a hand wheel by the side of the switchboard, so that the upper electrode can be raised or lowered at will by the switchboard attendant.

Supports and connections to the electrodes

"During use the upper electrode consumes at the rate of about $\frac{1}{16}$ inch per working hour.

"The materials employed in the manufacture of calcium carbide are lime and coke, and, incidentally, the carbon of the electrodes.

The preparation of the materials used

"The coke and lime are first passed through a crusher, and are subsequently ground by rollers. They are then thrown in proper proportions into a revolving ball mixer provided with pebbles. The operation effects an intimate mixture between the pulverised coke and lime.

"The coke and lime, after being separately pulverized, are weighed out in suitable proportions into the ball mixer. The lime is pulverised fine enough to pass through a 20-mesh sieve, and the coke is pulverised fine enough to pass through a 50-mesh sieve."

The first carbide works at Niagara

Later on Messrs. Morehead, King and de Chalmot, in erecting works at Niagara, altered the form of the furnace so as to get it into a more workable shape,

and also improved the method of introducing the mixture of lime and carbon to the arc and of the removal of the ingot when formed.

The Niagara furnaces

The bottom of this furnace was an iron car, *a*, running on rails, having on its floor a layer of carbon connected to the negative electrode. The positive pole was then brought down on to the layer of carbon, and the mixture of powdered lime and coke fed to the arc through shoots, *e e*, whilst an oscillatory motion was imparted to the car by means of the rod *g*, which

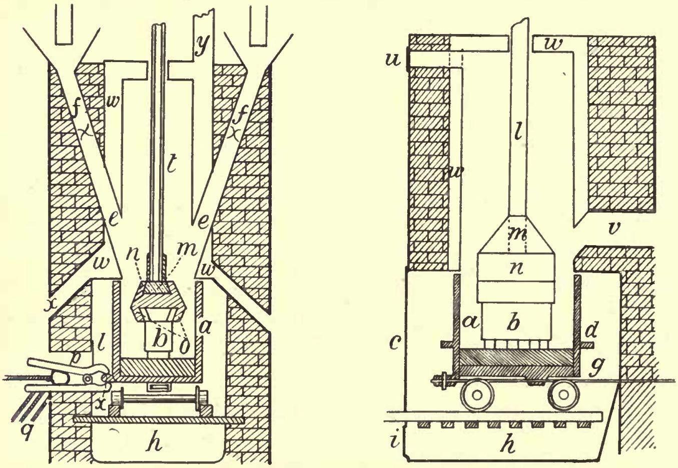


FIG. 50. SECTIONS OLD NIAGARA FURNACE.

moves the car backwards and forwards a distance of about two inches twenty times a minute, thus preventing the formation of layers and crusts. The carbon electrode is gradually raised as the height of the carbide in the car increases, until the car is completely filled by an ingot of carbide. An empty car is then put in the place of the full one, the pole, *b*, is lowered, and the operation commences afresh. The loaded car is run out, and after cooling, which takes from six to twelve hours, its contents are tipped upon an iron

The working of the furnace

grating, which permits all the dust and uncombined charge to pass away from the ingot. All the doors of the furnace are kept closed during the operation, except *u*, which is allowed to remain open in order to facilitate the expulsion of the air by the furnace gases, but this door is also closed when flames begin to appear. By this means the formation of explosive mixtures with carbon monoxide is prevented. The chimney, *v*, conducts the hot gases from the top of the car, so that

Prevention of explosive mixtures of gas and air

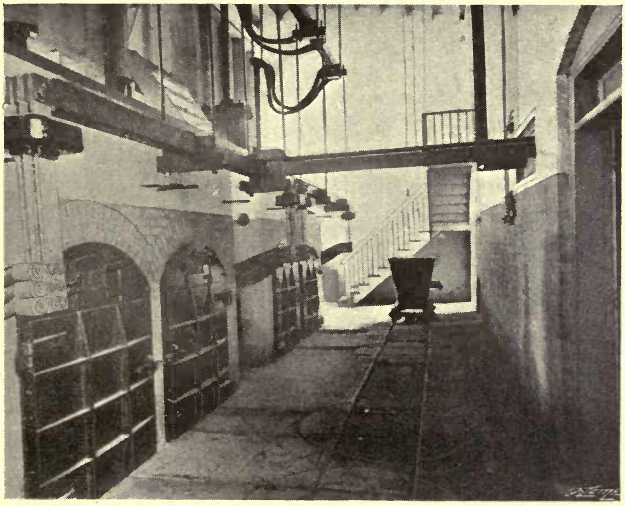


FIG. 51. EXTERIOR OF WILLSON FURNACES AT NIAGARA.

the carbon clamp and rod are not subjected to the hot gases. An air jacket, *w*, also aids in keeping the upper part of the furnace cool.

Willson's plant at St. Katherine's

In 1896 Mr. T. L. Willson, the original discoverer of the method of making commercial carbide, erected works at Merritton, near St. Katherine's, Ontario, on the old Welland Canal, the power being obtained from three locks, having each of them a fall of about 12¼ feet, two pairs of 50-inch turbines being worked at each lock, giving a total of 1,650 E.H.P.

Water power and dynamos

The dynamos used were 150 kw. 60 volt machines, having a stationary armature and a revolving field.

Labour-saving appliances for preparing the material

The arrangements for grinding and mixing the materials were very complete, the lime and coke being unloaded straight from the truck into a hopper connected with the boot of an elevator, upon which they were carried to the crushers on an upper floor. After being ground, the materials were screened to remove improperly ground portions, and then carried to rotary mixers, where they were thoroughly incorporated and fed to the furnaces, no handling of the materials taking place after they had been unloaded from the truck.

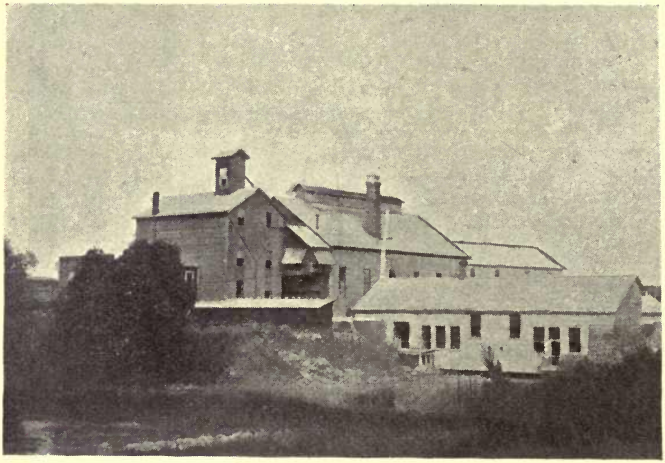


Fig. 52. The Merritton Works.

Furnaces

The furnaces were of the same type as those first used at Niagara, and each one took about 200 E.H.P. and made 500 lb. pigs, or ingots of carbide, per twenty-four hours.

Electrodes

The carbons used were six inches thick, a foot broad, and eighteen inches long, and were held in position by a chain hoist, electrically regulated. The unit of

electromotive force used was 75 volts, the current varying from 1,600 to 2,000 ampères.

Ingot furnaces and their general working

In furnaces such as those used until lately at Niagara, Spray, Foyers, and other leading carbide works, the crucible consists of cast iron, having a very heavy bottom protected by a lining of powdered carbon mixed with tar and then stamped hard. This

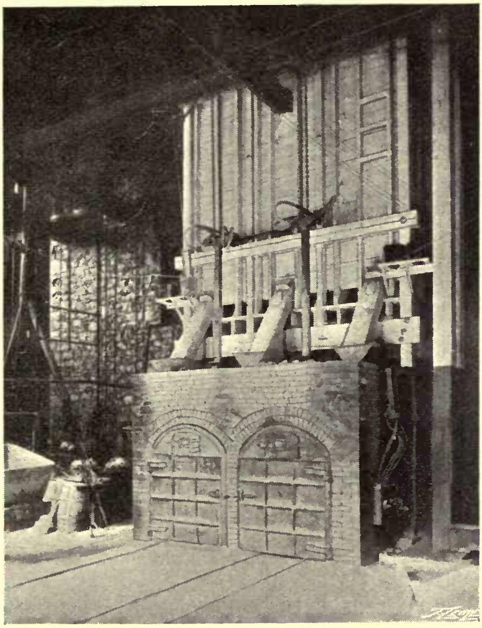


FIG. 53. THE FURNACES AT MERRITTON.

crucible is mounted on a bogie, running on rails in such a way that it can be wheeled under the brick chamber forming the outer wall of the furnace until it is in position below the movable carbon of the circuit, the heavy metallic bottom being then connected with one terminal of the dynamo. The upper electrode consists of carbon blocks, generally banded together, and suspended from a heavy metal clutch which is in

Details of construction

metallic connection with the other dynamo terminal. This upper electrode hangs vertically over the centre of the crucible when the latter is in position for use, and is capable of considerable vertical movement, which can be controlled by hoisting gear so as to regulate the distance between the two poles.

The outer casing of the furnace

The arched firebrick structure which forms the outer casing of the furnace, the ends of which are closed by iron doors to allow of wheeling in and out the crucible on its bogie, generally carries upon the top bins con-

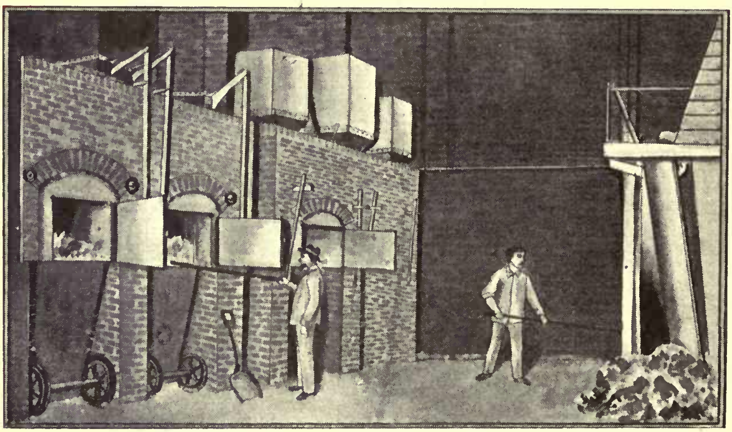


FIG. 54. WILLSON FURNACES.

taining the raw and pulverised material, which, on the opening of suitable valves by the furnace man, allow the mixture to descend by sloping shoots into the crucible.

Raw material acting as an insulator

The possibility of using cast iron crucibles depends upon the fact that the arc and the ingot as it grows are surrounded by a considerable amount of raw material.

The troubles incidental to this class of furnace

The trouble incidental to this class of furnace is largely dependent upon the amount of dust thrown up from the top of the crucible by the escape of the car-

bon monoxide and by the heat generated above the mixture by the burning of this gas as it comes in contact with air, which necessitates the carbon holders being made extremely massive in order to prevent their opening and allowing the carbons to fall into the furnace. The dust also gives considerable trouble in keeping the contacts clean, and unless the contact, especially on the bottom plate, be perfect, the lower portion of the crucible will frequently burn out. All contact surfaces must also be of very heavy metal in order to prevent warping by the heat, which would destroy the contact and give rise to considerable damage, as the current passing into a 200 H.P. furnace would be between 2,000 and 3,000 ampères.

The dust nuisance

As has been before pointed out, the chemical actions involved in making calcium carbide from lime and carbon consist in first reducing the lime to metallic calcium with evolution of carbon monoxide, whilst the calcium at once combines with the excess of carbon present, forming calcium carbide. The carbon monoxide so produced is an inflammable gas burning with a very hot flame, and this gives rise to considerable trouble at the top of the furnace. The carbon blocks forming the upper terminal are very expensive, and for economical working it is necessary to do everything that is possible to preserve them from destruction, and if any length of this carbon electrode is exposed above the crucible, the flame of the burning carbon monoxide playing upon it will lead to its rapid destruction, no matter how good the quality of the carbon employed may be, whilst if, as the carbon grows shorter, it is completely buried in the pulverized material, the carbon holder is liable to be rapidly destroyed, and it is by no means an uncommon occurrence for the metal clutch to be fused down into the furnace below.

The production of inflammable gases in the furnace

The burning and waste of the upper electrodes

In order to meet this difficulty at Foyers they use a patented process by which specially made crucibles are

Foyers process for preventing

burning of electrode

provided with a number of holes at the ends, and a passage is cleared by means of an iron rod through the mass of material in order to allow of the escape of the carbon monoxide through these holes instead of upwards, and where this is done the carbons used are generally about 30 inches in length and are buried up to within a few inches of the carbon holder.

Most American manufacturers encase their carbons in sheet iron, which is allowed to burn away with the

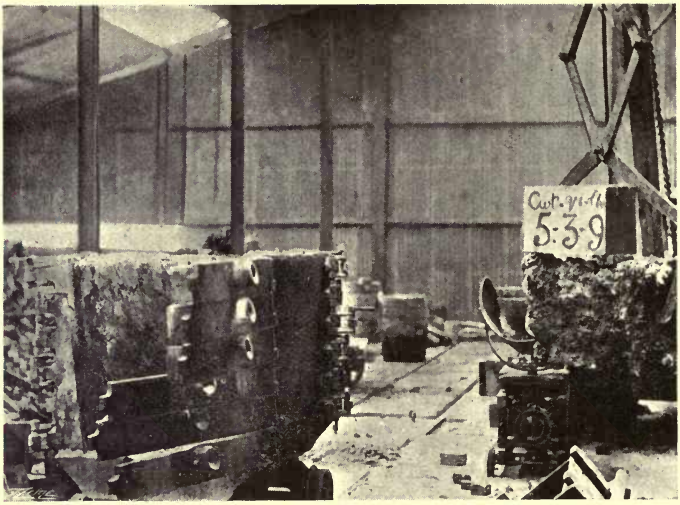


Fig. 55. Foyers' Crucible, showing Patent Front.

electrode, but it is manifest that this will slightly add to the impurity of the carbide.

Drawbacks of over-heating

Directly the combination has taken place between the calcium and the carbon to form the carbide, it is of the greatest importance that the material produced should be withdrawn as soon as possible from the temperature of the arc, as otherwise dissociation may take place, and a "burnt carbide," having but a low gas yielding power, be produced. One of the points of the utmost importance in good carbide making is

to so arrange the current density as just to reach the combining temperature, and not to get to the point at which dissociation occurs. The general idea is that in order to do this the raw materials have to be very finely ground and very intimately mixed.

Current density

The Willson type of crucible furnace is now being abandoned in America, and is being replaced by continuous ingot furnaces. In the old works at Niagara, and also the works at Saulte Ste. Marie,

Introduction of the "Horry" furnace

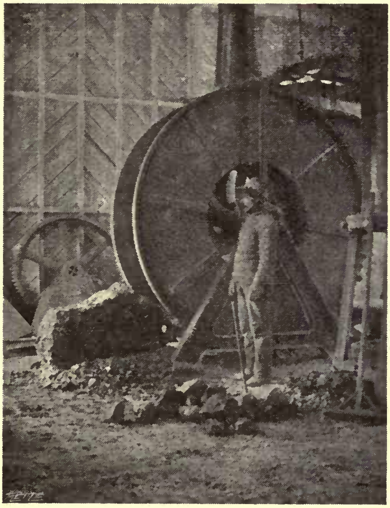


FIG. 56. HORRY ROTARY FURNACE.

where Lake Superior empties itself into Lake Huron, and where an enormous volume of water falls about 19 to 20 feet, Horry rotary continuous furnaces (Fig. 58) were introduced two years ago.

In the Horry furnace, instead of the upper carbon pole being slowly raised as the height of the ingot of carbide increases, the arc is produced at a fixed point, whilst the furnace into which the raw materials are fed can be gradually rotated by suitable gearing.

Construction of the "Horry" furnace

In the Fig. 57, *a* a^1 are the carbon poles with their lower ends bevelled so that a vertical passage, *b*, is formed in which the arc plays, and through which the material to be treated is fed. The body of the furnace, *c*, is spool-shaped, and is mounted on suitable supports, *d*, whilst it can be rotated by the worm gearing *e*, e^1, e^2 (Fig. 58). Coverplates, *f*, can be

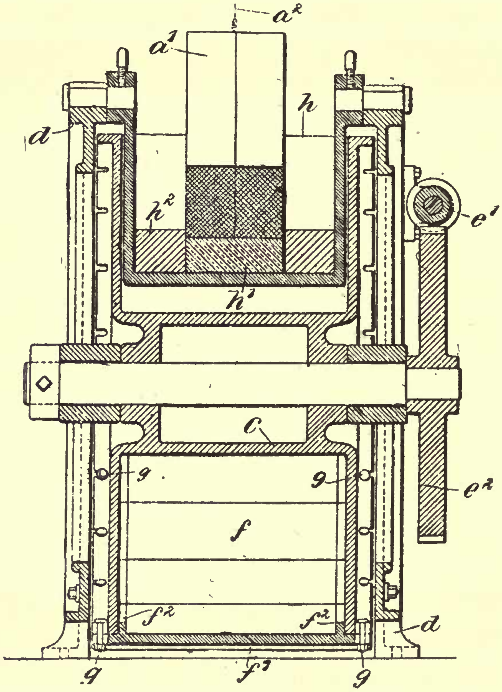


FIG. 57. HORRY FURNACE.

attached to the periphery of the furnace, *c*, and are secured to it by bolts or clips, as at *g*. The carbon poles are supported by the sides of the hopper, *h*, which is lined with fire-clay or other refractory material, and contains the mixed lime and coke.

General working of the furnace

When the circuit is closed, the mixed materials pass through the arc in the passage, *b*, and the molten

carbide falls into the receptacle *c*, where it gradually builds up, at the same time lowering the electrical resistance. When this is shown by the rising of the ammeter, the worm gearing is put in action, causing the receptacle, *c*, to move, carrying the carbide away from the arc, and allowing fresh material to be acted on. As the receptacle is rotated, fresh plates must be added at *F* to retain the material. The

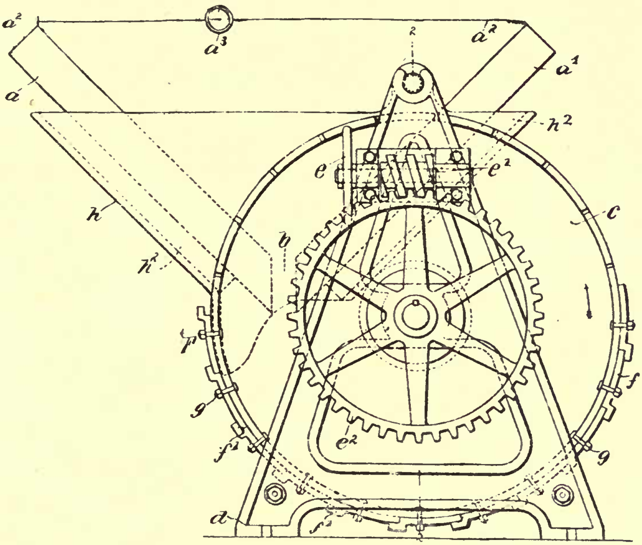


FIG. 58. HORRY FURNACE.

carbide thus forms a ring or part of a ring, and, when it has travelled to the other side of the furnace, the peripheral plates are removed and the carbide broken away. In this way the process is continuous until the carbons are consumed.

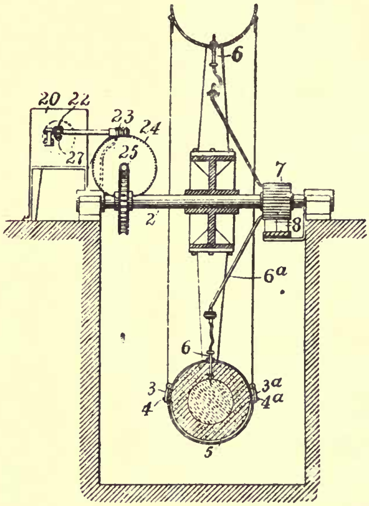
Another continuous rotary furnace of the same class is that patented by Bradley, which differs from the Horry furnace by making the core of carbide one of the poles, and as far as possible reducing the resistance of the mass of carbide as it is formed, by bringing the

The Bradley rotary furnace

current as near to the arc as possible by means of copper plugs inserted at intervals in the rim of the furnace.

Construction of the Bradley furnace

The furnace consists of a rotating wheel (Figs. 59 and 60), with semicircular rim to which semicircular plates can be attached, forming a circular chamber. The wheel may be 15 feet in diameter, and the chamber, 36 inches in diameter, is sunk into the ground



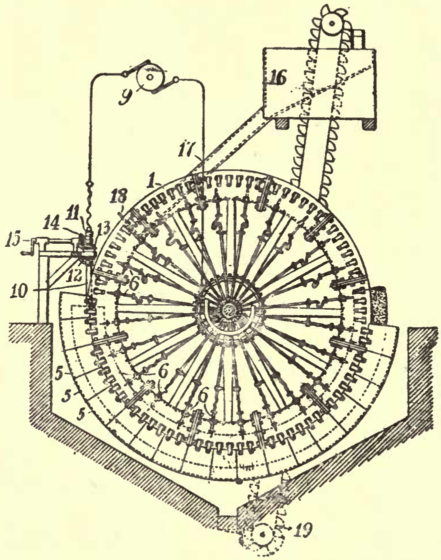


FIG. 59. BRADLEY FURNACE. FIG. 60.

so that its axis is carried on journals on the floor level. This wheel can be slowly rotated by means of power-driven gearing. At the floor level the carbon electrode projects into the hollow rim. At intervals on the inner wall of the rim are copper plugs connected with a commutator on the axle of the wheel, which is in electrical communication with the dynamo supplying the current. Automatic means are provided for the supply of the charge.

The action is as follows: A charge of the mixed materials falls into the chamber round the electrode until its top is immersed therein. The current is then started, and, as the charge is moved away by the rotation of the furnace, an arc is created, and the charge fuses forming a pool of liquid carbide surrounded by unacted-on material which protects it from atmospheric influence. Fresh rim plates are added as necessary with the turning of the wheel, and in this way a circular core of carbide is formed, which is surrounded by unacted-on material. When the core of carbide has reached the other side of the furnace, the rim plates are removed one by one and the carbide is broken off. The powdered material falls into the pit in which the wheel works, and is carried by an elevator to the feed-hopper. The copper plugs form an electrical connection for the passage of the current through the formed carbide, thus dispensing with a second electrode; whilst the commutator causes most of the current to enter by the plug nearest the arc, and avoids the introduction of unnecessary resistance.

Working of the furnace

Means taken to diminish resistance

The Union Carbide Company are the largest manufacturers of calcium carbide in the world, and utilise 15,000 H.P., at Saulte Ste. Marie (Fig. 61), whilst the chief feature of 1899 in the manufacture of calcium carbide is the completion of this company's new works at Niagara Falls, which are capable of giving an immense increase in output upon those which formerly existed there.

The Union Carbide Company's Works at Niagara

These works are equipped for receiving and utilising 25,000 E.H.P. per day, which is probably the largest amount of E.H P. which is used by any one works in the world.

The works are designed and made to manufacture as nearly automatically as possible, the furnaces and conveying machines being all under automatic control.

Process employed

Rotary furnaces, constructed under the Horry and Bradley patents, are employed, and embody some important improvements over those which had already been in use in the old works, and also at the works at Saulte Ste. Marie.

Power used

These new works cover about 10 acres, and the electrical current used is generated at the power house

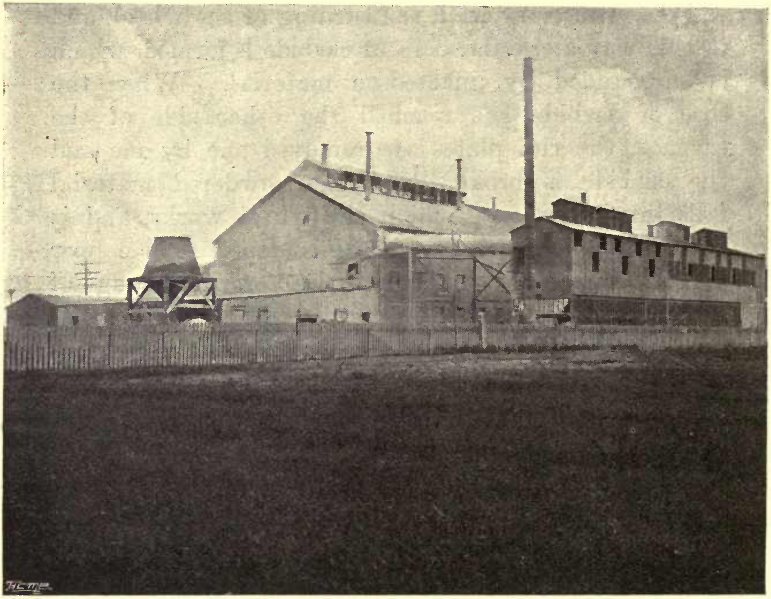


FIG. 61. UNION CARBIDE WORKS, SAULTE STE. MARIE.

of the Niagara Falls Power Company at 2,200 volts pressure, which is then transformed for conveyance to the carbide works to 10,000 volts pressure, and at the works is reduced by a series of transformers to the required voltage for the furnaces.

Whilst these changes had been taking place in America, the manufacture of carbide had also been steadily progressing in Europe. A considerable quantity of carbide was imported into England in 1894,

FIG. 62. NIAGARA TRANSFORMER.

and a syndicate having acquired Willson's rights, erected in 1895, at Leeds, an experimental plant on a large scale, capable of working continuously at from 60 to 70 volts at 1,000 to 1,200 ampères. Steam power was used to drive the dynamo, which was of Desrozier

The Leeds plant

type, with multipolar field and disc armature. The electric furnace consisted of a heavy iron bed plate, connected with the negative pole of the dynamo, whilst the positive electrode consisted of a carbon rod eight inches square, the height of which above the bed plate could be adjusted by a rack and pinion.

Dynamo and furnace

This installation, which is of interest from the fact that it was the first of the kind in England, is shown

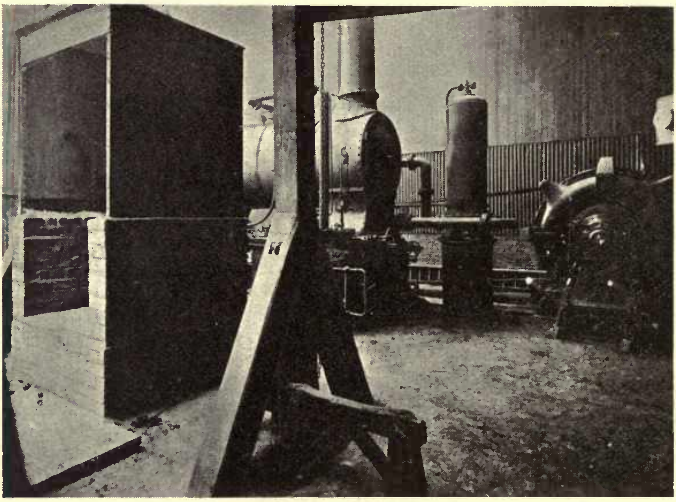


Fig. 63. Leeds Plant.

in the two accompanying figures, Fig. 63 showing the dynamo, whilst Fig. 64 makes clear the arrangement of the furnace.

The working of the plant

In using this furnace fire bricks were placed upon the bed plate so as to form a chamber beneath the carbon pole, and the latter being lowered until it struck an arc with the plate; the material to be fused was shovelled into the chamber around the pole, and, slipping under it, became subject to the full force of the arc. More and more material was then put in,

and was, as far as possible, driven in under the pole by a wooden rammer.

Having demonstrated at Leeds the possibility of making calcium carbide by electrical power in such a way as to be a commercial success, attempts were made to obtain water in place of steam power, and, finally, the Acetylene Illuminating Co. leased a portion of the surplus power existing at Foyers, which is

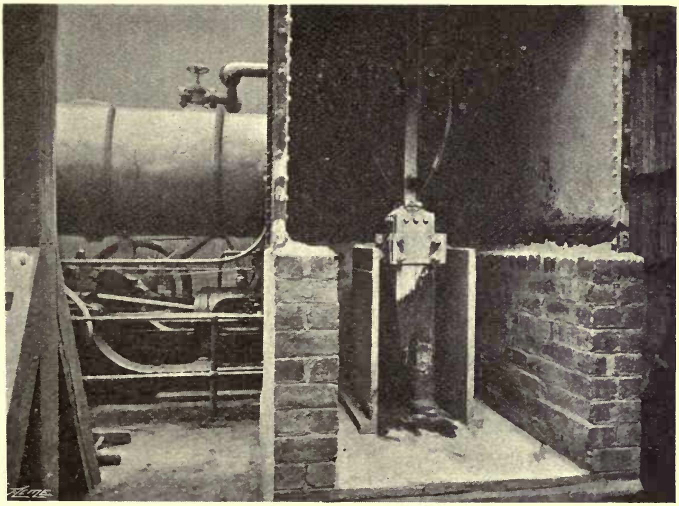


Fig. 64. Leeds Furnace.

still the only installation of water power of any considerable magnitude in Great Britain.

The water power at Foyers

The Falls of Foyers have long been noted for their beauty and for the large fall of water which descends in all save the dryest seasons. The Falls are situated on the south-east side of Loch Ness, which forms part of the Caledonian Canal, where the land rises to a height of 600 to 2,000 feet above the Loch level. Loch Garth and Loch Faraline are situated in a valley running parallel to Loch Ness at the higher level, and

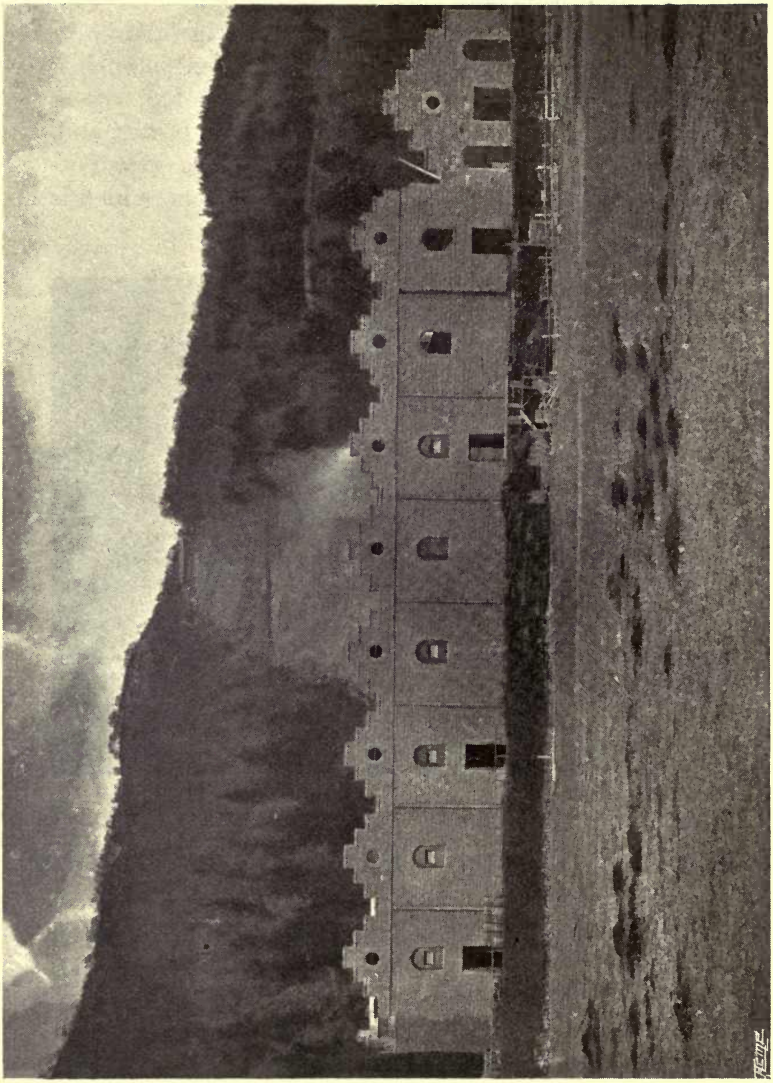


Fig. 65. The Electrical Power Works at Foyers.

the water from these lochs, as well as the water from other smaller ones, is discharged over the Falls of Foyers.

A stone-built dam was erected at the southern end of Loch Garth across this upper valley, and forms a reservoir five miles long by three-quarters of a mile wide, capable of containing four thousand million gallons of

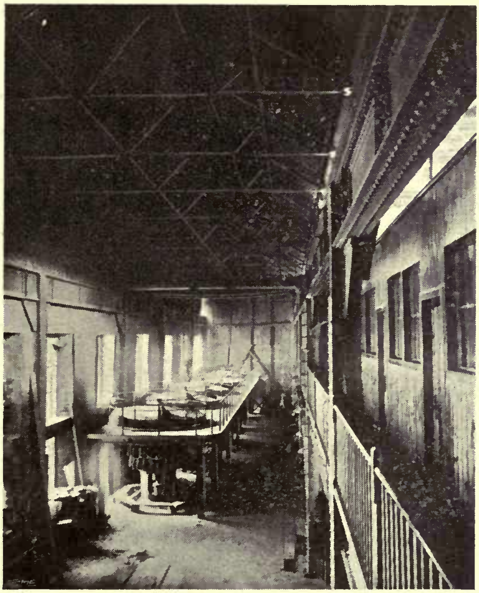


FIG. 66. THE DYNAMO ROOM, FOYERS.

water. From this a tunnel was built, and the water brought down by six lines of cast iron pipes to five large turbines below which drove the dynamos, each of about 700 H.P. The turbines and dynamos are mounted on the same shaft, and are driven at the rate of about 150 revolutions per minute. Each dynamo yields over 8,000 ampères, and it is a portion of this power that is utilized for making the carbide. **Foyers turbines and dynamos**

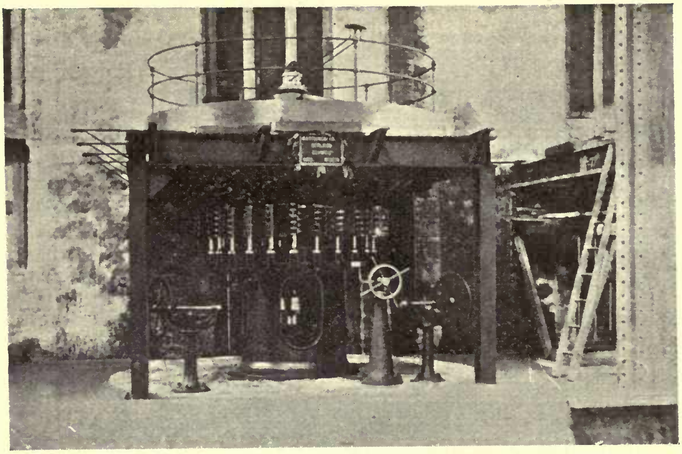


FIG. 67. A FOYERS DYNAMO.

The turbines employed at Foyers are the Escher Wyss, whilst Oerlikon dynamos are used. These are of solid construction, the armature alone weighing 14 tons. They are of the smooth core multipolar drum type, having 24 field poles and 24 brush spindles,

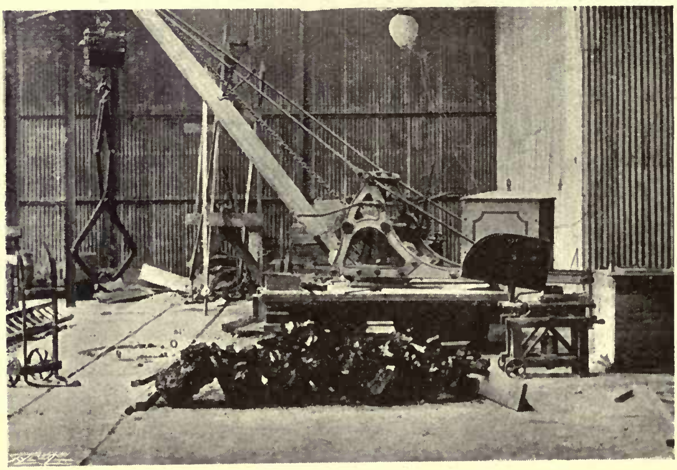


FIG. 68. THE INGOT ROOM AT FOYERS.

carrying 60 positive and 60 negative brushes, each 2 inches wide and $\frac{1}{2}$ inch thick. The output of the dynamo when the turbine sluice is fully open is about 500 kilowatts at 55 to 60 volts. **Electrical output**

The current is led direct from the dynamo to the furnaces by means of bare copper strips, laid in the ground with flexible cables to the carbon holders. The main cables are 16 square inches in section, and **Connections**

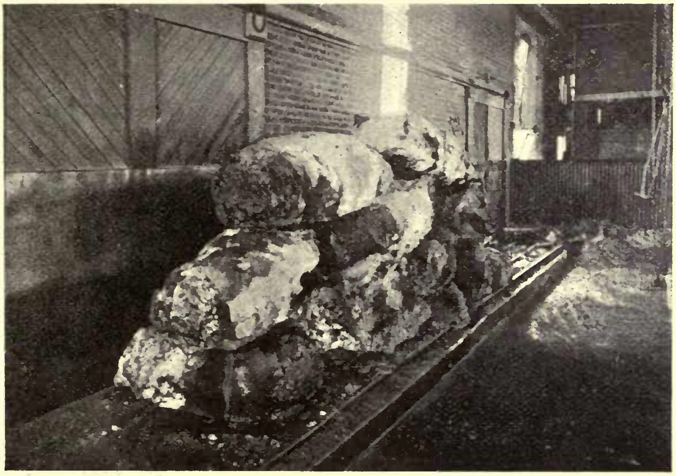


Fig. 69. Ingots Cooling, Foyers.

are made up of 32 strips, each 2 inches wide by $\frac{1}{4}$ inch thick, divided by distance pieces.

The furnaces are of the Willson type, but an important modification has been introduced in the crucible (*see page* 206), which is a heavy cast iron truck running on rails, the ends of which are built up of a number of narrow iron slips or doors, in the centre of each of which is a hole. These slip doors are so made that any one can be opened separately; and it is found that this arrangement gives considerable economy in the process, as the carbon monoxide generated by the **The Foyers furnaces**

reaction in the furnace escapes laterally and burns at the end holes, instead of being driven upwards and burning at the top of the fuel, thereby saving overheating and burning to waste of the upper electrode.

French carbide furnaces

In France, as soon as American action had drawn attention to the commercial importance of calcium carbide, Bullier, who had been associated with Moissan in his classical researches with the electric furnace.

FIG. 70. AN INGOT OF CARBIDE, FOYERS.

introduced a form of furnace of the same type as that used in America, with the exception that instead of making the crucible a truck which could be removed with the ingot in it, the body of the furnace was fixed, and a horizontal movable bottom, which could be opened when the operation was completed and the ingot of carbide dropped out, was used.

Bullier ingot furnace

This furnace was lined with refractory material such as magnesia, the bottom being closed by a mov-

able plate of metal and carbon, *b b*, which formed the negative pole. The positive pole consisted of a carbon rod *c* embedded in the mixed lime and coke. Contact was made by bringing the positive carbon on to the

Construction of the furnace

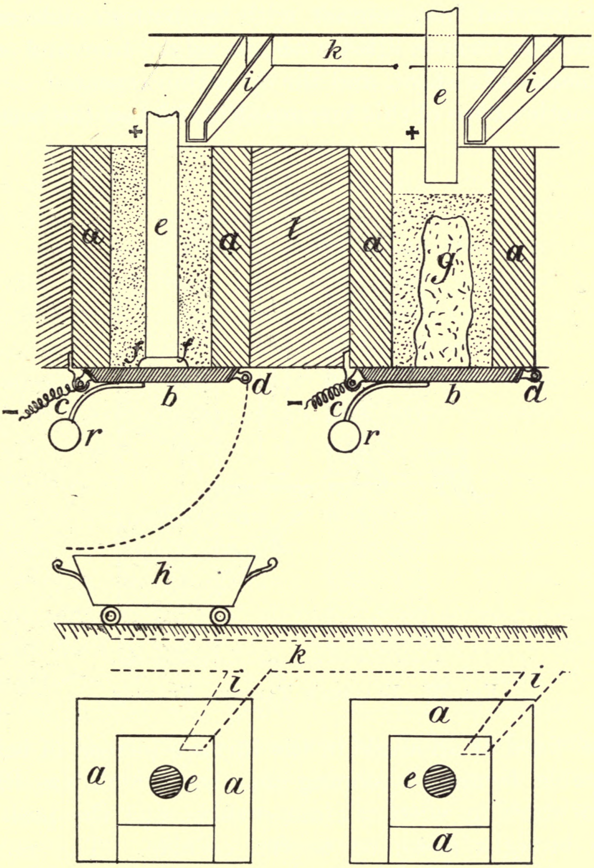


Fig. 71. Bullier's Furnace.

negative plate, and as the material surrounding the carbon became fused with formation of liquid carbide, the carbon rod was gradually raised. The unacted on material served as a non-conductor of the heat and

confined it within narrow limits. After the operation was complete and the current was cut off, the bottom plate was opened and the ingot, with any mixture still unacted upon, dropped into a car and was removed for breaking up and packing. The positive electrode was then lowered into contact with the bottom plate once again, the furnace filled with the mixed lime and coke by means of a shoot, and the operation repeated.

Another type of this furnace (Fig. 72) had the bottom

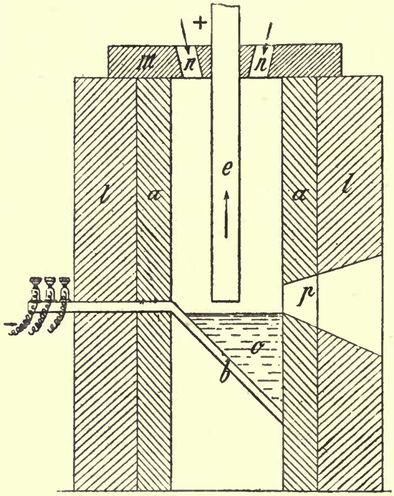


FIG. 72. BULLIER'S TAPPING FURNACE.

Bullier running furnace

plate fixed at an angle in the furnace instead of being movable, forming a sloping chamber, which was filled when starting with calcium carbide, and the positive pole brought down on to the carbide. The mixed lime and coke was fed through holes in the cover of the furnace, and the melted carbide withdrawn from time to time by tapping the furnace just above the top level of the sloping chamber.

From a commercial point of view the most important development in the method of making calcium

carbide in Europe was an outcome of the use of the Heroult furnace in the manufacture of carbide.

The Froges works

Works had been established by the French Society of Electro-metallurgists for the manufacture of aluminium by the Heroult process at Froges, near Grenoble, consisting of three turbines, each of 500 H.P. Two of these were connected with a Brown continuous current dynamo of 6,000 ampères, 60 volts, and the other with one of 500 ampères and 65 volts, the current from which set in motion the two large dynamos. Both generators are capable of feeding three furnaces at a distance of five metres; but only three furnaces were actually used, and never more than two were worked at the same time, each being supplied by a special dynamo, whilst they are stopped in turn so that the crucible, which requires frequent repairs, may be attended to. The furnaces were identical with those used in making aluminium, and were provided with wheels to admit of easy adjustment and removal.

The Froges furnaces

The furnace was rectangular, 1·8 × 1·5 × 1·5 metres in size, and consisted of a graphite crucible with an external coating of cast iron, communicating at the top with a charge opening and at the bottom with another orifice, in front of which was placed a receiver for the melted material. The cables of the negative conductor were fixed by bolts to the back wall of the furnace, whilst the positive electrode consisted of a carbon rod, held in position by four claws, above which were attached six cables supplying the current. By means of screw-gearing the electrode could be raised or lowered, the shaft of the screw passing through a collar forming part of a crutch fixed to the skeleton framework, and also to a screw wheel above the collar which gears with a pinion, the shaft of which crosses the crutch and can be worked by hand. The formation of calcium carbide is very simple. The crucible is filled through the charge opening with a mixture of

The arrangement of the furnaces

The method of working the Heroult

furnaces at Froges

lime and coke, whilst a workman in charge of the furnace, protected against the enormous heat by a mica screen, stands by to work the pinion shaft.

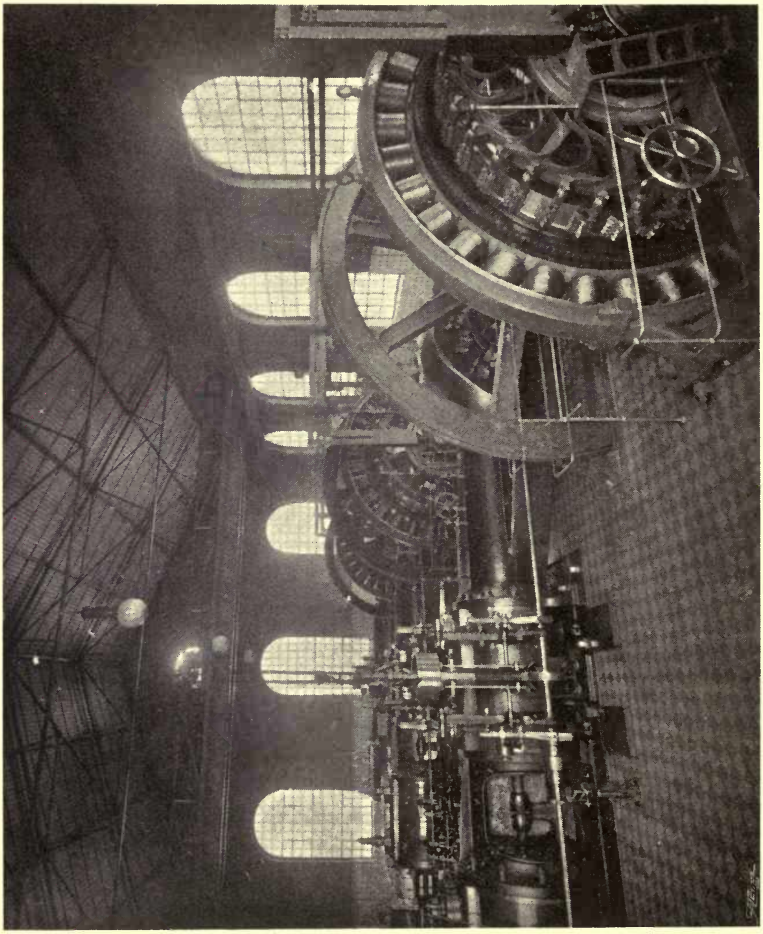


FIG. 73. STEAM-DRIVEN DYNAMOS AT BITTERFELD.

When the crucible is full the electrodes are gently lowered by turning the hand-wheel, and the arc is at once struck between the positive electrode and the material in the crucible. The carbon becomes red-hot

almost throughout its entire length, and a long flame escapes at the charge opening. The position of the electrode is regulated according to an am- and voltmeter in the circuit, and the progress of the action is judged by the size and colour of the flame. When the operation is over the bottom orifice is opened, whilst the crucible is again filled at the charge-opening and the molten carbide flows in an incandescent stream into the trough placed to receive it, and there cools.

The electrode still remains plunged in the crucible, and the current consequently is uninterrupted. The work of the furnace is thus continuous, proceeding by successive relays, being emptied about every forty minutes. Each furnace is capable of supplying about 300 kgr. of carbide per diem, and is kept in use for the whole twenty-four hours.

Output of the furnaces

The electrodes form the most expensive portion of the apparatus, being quickly consumed by the great heat at which they are kept, but the Electro-metallurgic Society make their own in special furnaces provided for the purpose.

Electrodes

Many modifications and some improvements of this type of furnace have been introduced, and at the big carbide factories of central Europe the "running" type of furnace is almost entirely used.

Central European furnaces

The Electro-chemical works at Bitterfeld were the first to manufacture calcium carbide on the Continent, and early in 1895 were using a furnace of the Willson type with 250 E.H.P., which was afterwards increased to 500 E.H.P.

The Early History of the continental Carbide Industry

The loss of material, and the differing qualities of carbide produced owing to the crust of partly formed carbide adhering to the ingot, caused them to abandon this process, and led to a number of experiments being made with the view of introducing a constant process in which the carbide could be regularly run off from

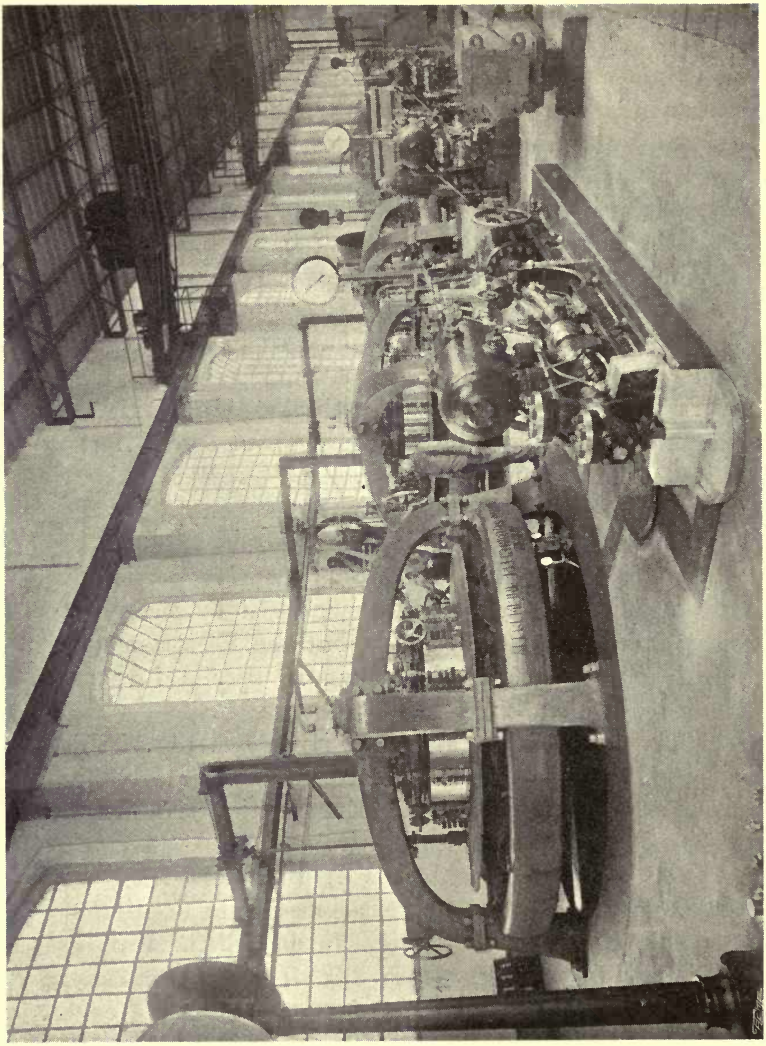


FIG. 74. TURBINES AT RHEINFELDEN.

Continuous furnaces

the furnace by a tap-hole on the hearth. Considerable difficulties arose in doing this, as the continuous high temperature was destructive to the furnace, and many other troubles had to be overcome.

By 1897, however, success had been attained, and steam power proving too costly, the Allgemeine Electricitats-Gesellschaft secured a portion of the 16,000 H.P. water power which had been harnessed at Rheinfelden, and erected a carbide factory, using the latest type of furnace. The furnaces have worked continuously since early in 1898 without interruption or

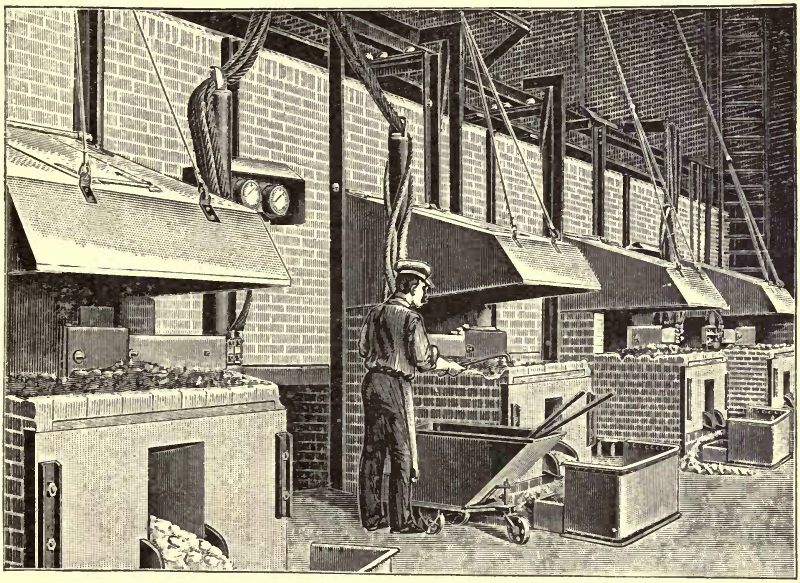


FIG. 75. DR. RATHENAU'S FURNACE.

difficulty, only stopping on the fixed holidays, such as Easter and Christmas.

The "Rathenau" furnace

These furnaces, which were designed by Dr. Rathenau, are shown in Fig. 75, whilst the construction will be seen from Fig. 76.

Construction of the furnace

The furnace consists of a fire-brick casing, with the bottom formed of a thick carbon plate resting on an iron floor, which forms one of the poles. The top of the furnace is closed by the carbon plate, *V*, through

which, but insulated from it, the upper carbon-pole passes. At one side of the cover is a sliding plate, *S*, which opens or closes the bottom of the shoot through which the mixed material is fed. The charge is passed in at one side of the furnace whilst the gases resulting from the actions going on escape on the opposite side of the furnace.

Working of the Rathenau furnace

The mixed material is allowed to flow into the furnace by the shoot *N*, the sliding plate being withdrawn, and falls into the arc. When the molten carbide is ready for tapping, the supply of lime and coke mixture is stopped by closing the sliding plate,

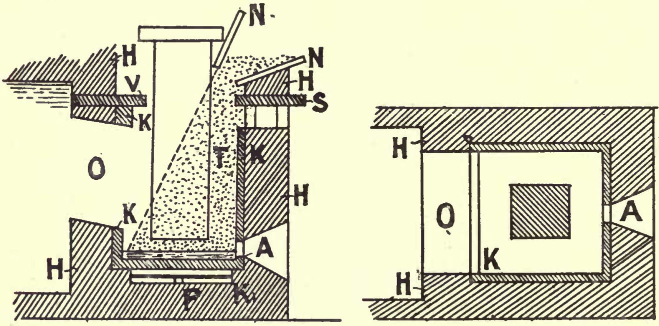


FIG. 76. SECTIONS OF RATHENAU FURNACE.

and as soon as the furnace-chamber has reached the right temperature, the carbide is run off through the tapping hole *A*. Fresh material is then gradually added by slowly opening the sliding plate, and in this way any rapid lowering of temperature in the furnace is avoided.

Every precaution is taken to prevent access of air, and by this means the loss in substance of the electrodes is limited to the action of the arc and the solvent action of the liquid carbon.

At the present time installations of upwards of 10,000 E.H.P. are either working or under construction in Europe on this system.

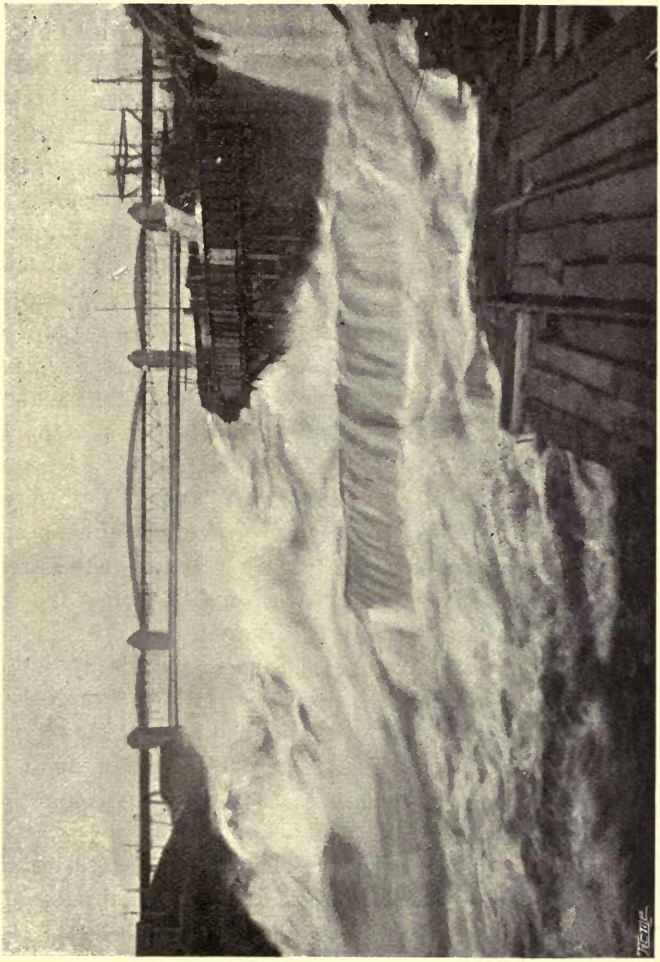


Fig. 77. The Hafslund Water Power.

The Schuckert Carbide Installations.

The Electricitats Aktien Gesellschaft, formerly Schuckert & Co., of Nurnberg, have built and equipped a number of big European carbide works, and are at present utilising about 30,000 E.H.P., although this by no means represents the total power at their disposal. At Hafslund, for instance, which is one of their

The Hafslund Works

biggest installations, the beautiful Sarpsfoss Waterfall is harnessed for over 20,000 E.H.P., but only about 7,200 of this is utilised at present, about 5,000 being employed in carbide-making, but this will very shortly be doubled.

General working of the plant

Six large and two small turbines and dynamos generate the power which is used in 24 furnaces of about 200 kw. each. These furnaces are arranged in two groups of 12, each group consisting of two rows of six furnaces, back to back, with a chamber between them, through which the gases are drawn off from the furnaces, and in which the dust settles.

The furnaces are modifications of the ingot furnace, and are fitted with a tapping hearth from which the liquid carbide is run off every hour, whilst an ingot slowly forms and is withdrawn every few days. Carbons made by Conradti and protected by a special mixture from combustion in the air are adjusted from above, and the carbide mixture is fed in from a trough which runs along above the furnaces.

The Sarpsborg Carbide Works

On the opposite side of the Sarpsfoss Falls, at Sarpsborg, the power belongs to the Kellner Partington Paper Pulp Co., who rent about 1,500 H.P. to the Allgemeine Carbid- und Acetylen-Gesellschaft, who manufacture carbide in the Rathenau furnace.

As has been pointed out, it was Siemens in 1879 who first made a practical electric furnace, and the great electrical firm of Siemens & Halske have during the past five years devoted considerable attention to carbide furnaces.

The Siemens-Halske carbide furnace

The Siemens-Halske furnace has gone through several modifications, a hollow upper electrode being first introduced with the idea of feeding the mixture of lime and carbon down through it to the arc. This was then abandoned, and the hollow electro retained to allow the escape of carbon monoxide from the action taking place in the arc, this being a great gain, as it

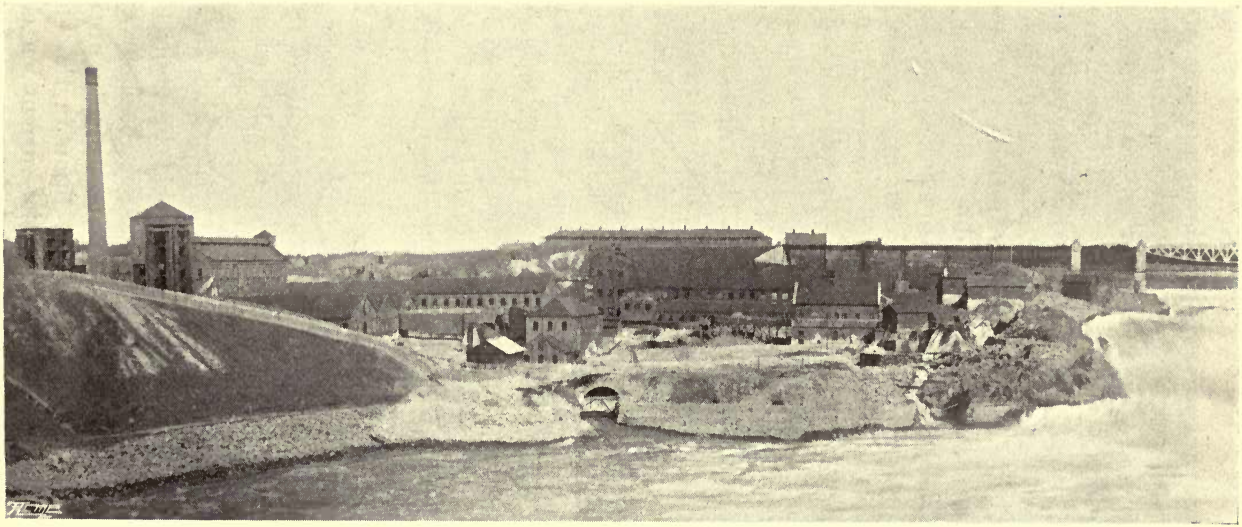


Fig. 78. General View of the Sarpsborg Power Works.

prevents the uprush of gas through the raw material, which always interferes with the proportions in which the lime and carbon reach the arc, the lighter portions being swept upwards. The negative pole consists of a sloping bed of carbon, on to which the upper electrode is lowered in order to strike the arc, and is then raised to the necessary height to keep the arc constant and to allow the charge to slip down the sloping carbon hearth into the arc, where fusion takes place.

Advantages of the hollow electrode

Construction of the modern Siemens-Halske furnace

The bottom of the hearth at first consisted of a movable block which could be lowered to allow the molten carbide to flow out, but it was soon found that the opening rapidly choked owing to the cooling of the carbide round the edges; but this trouble has now been surmounted by having a large iron elbow tube, with a movable end, below the opening in the bottom of the furnace, and filling this with coarse carbide mixture into which the fused carbide drips, and as it accumulates, gradually pushes the mixture out of the tube, cooling, in this way, out of contact with the air.

The flexible end to the tube can be replaced by a door or trap. The carbon monoxide led away through the hollow electrode can be conducted to a gasholder or utilised direct for burning the lime used in the mixture.

Construction of the hollow electrodes

The great trouble found with this form of furnace was the impossibility of making the hollow carbon electrodes of even density, as they are about 18 inches external diameter and the hole 9 to 10 inches across, and a little over a metre in length. This has now been got over by making the tube in a number of sections keyed together and held in position by a metal band. The hollow electrode burns away with perfect evenness, the arc being equally distributed around it, any inequality or lump in the electrode causing a concentration of the current on the projection at that point, which is therefore burnt away. It

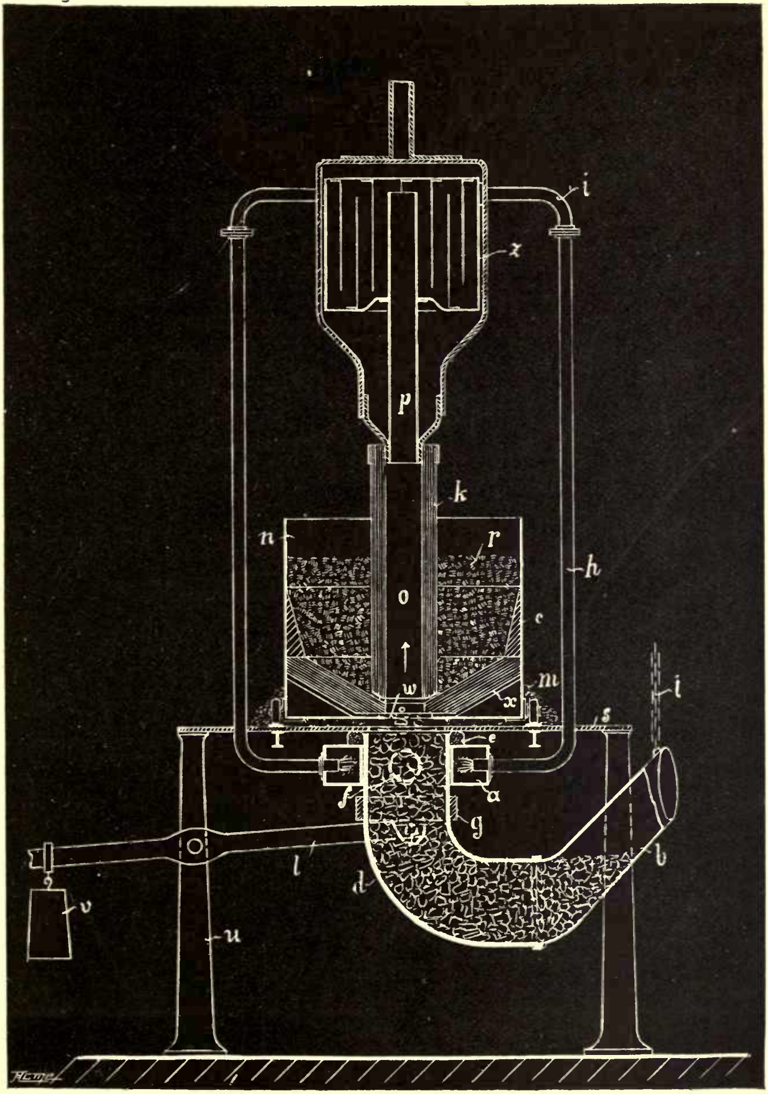


FIG. 79. SECTION OF THE SIEMENS-HALSKE FURNACE.

is found that about 21 mm. of the electrode are burnt away per hour, and the cost of electrode per ton of

Output of the Siemens-

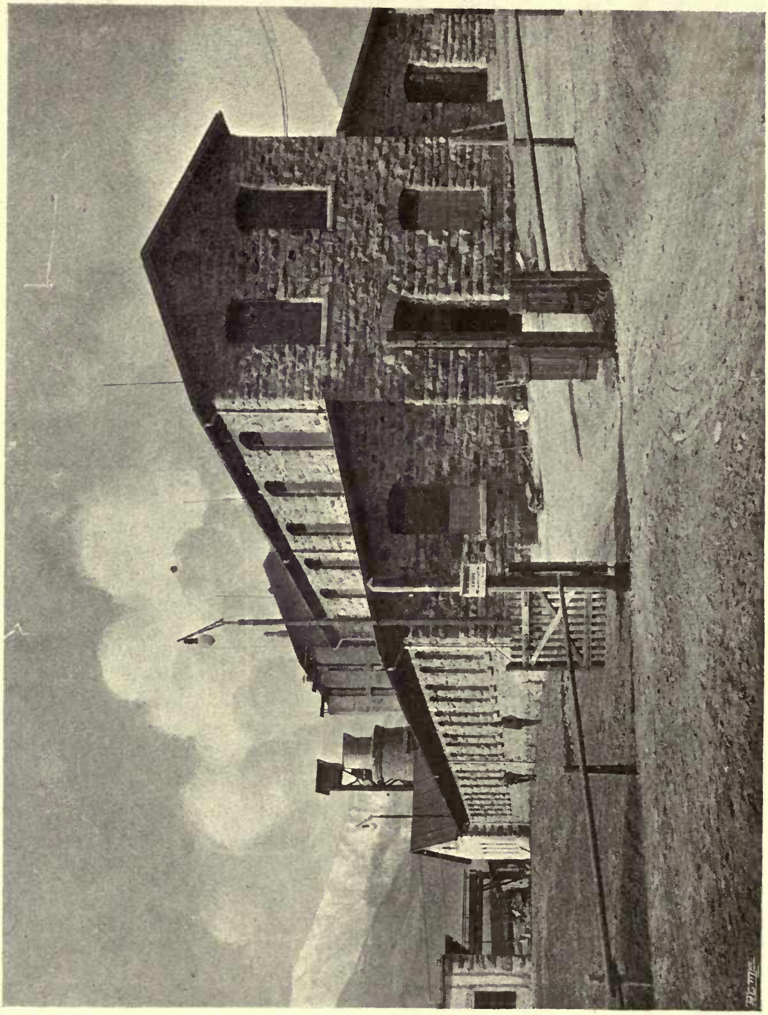


FIG. 80. THE WORKS AT MERAN.

Halske furnace

carbide only amounts to about 10*s*. The furnace is said to yield $5\frac{1}{2}$ kilos of carbide per kw. day, and is guaranteed to give 5.

American hollow pole furnace

An electric furnace with a heavy hollow upper pole, down through which the carbide mixture is fed, has

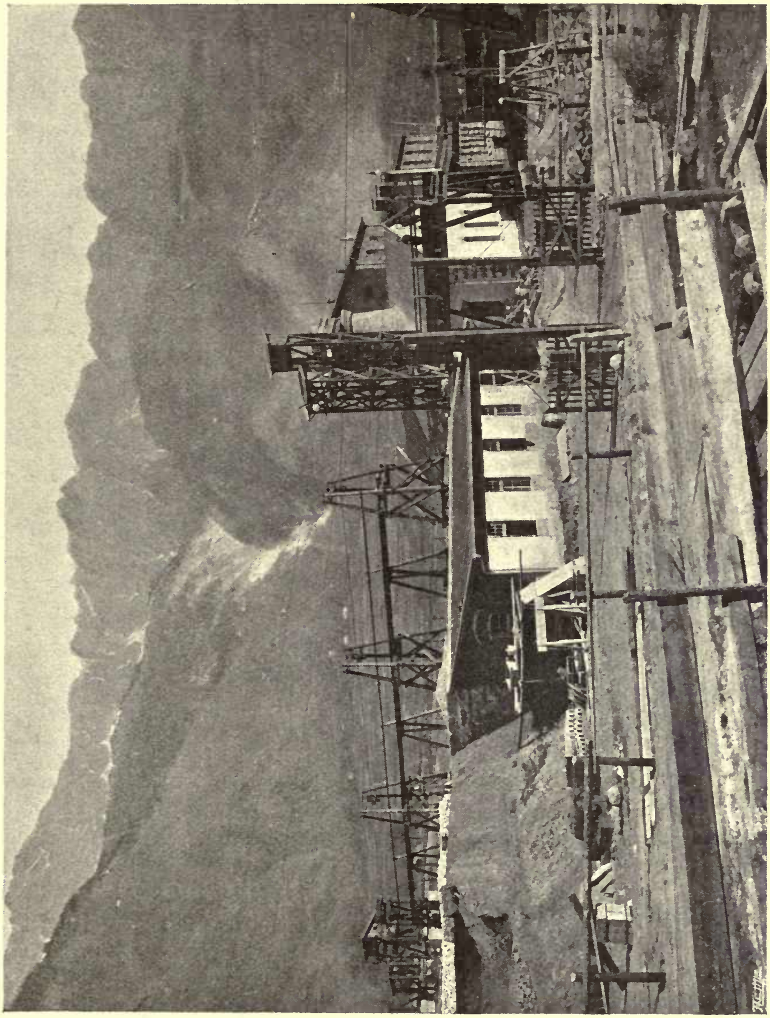


Fig. 81. General View of the Meran Factory.

lately been tried at the Armour Institute of Technology, Chicago, but without any very promising results, the difficulties of the feeding being very great.

Another development of the running process, in

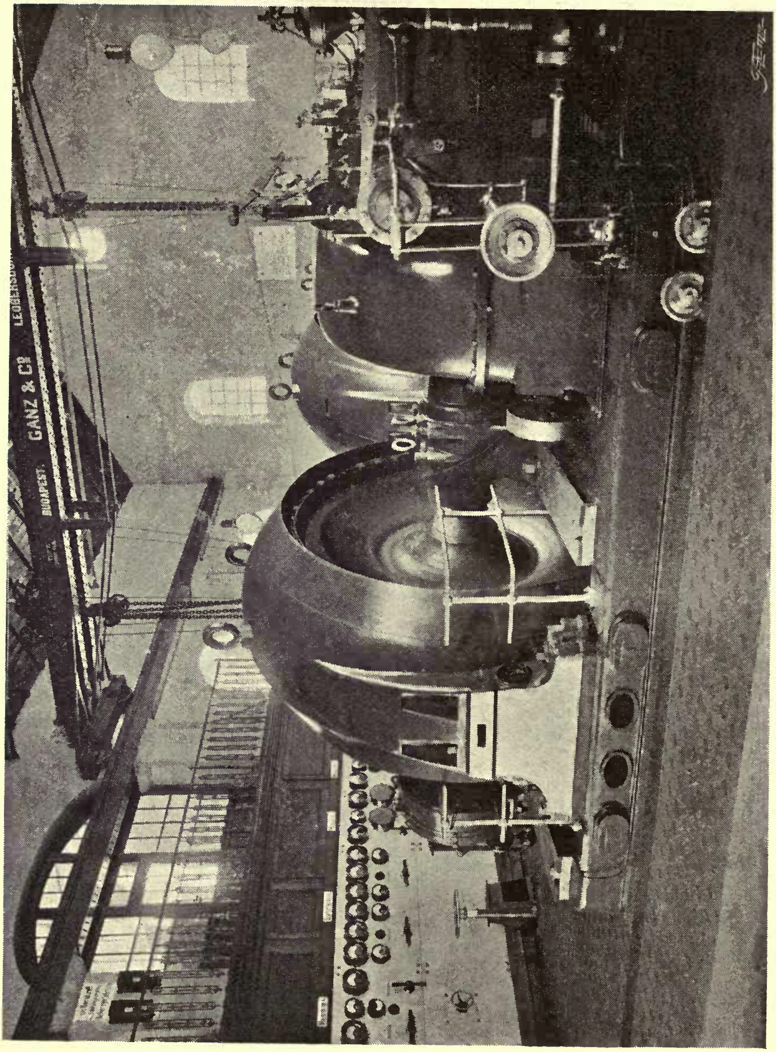


Fig. 82. Turbines at Meran.

Gin & Leleux process

which the carbide is made partly in a sufficiently fluid condition to be tapped from the furnace and partly in the form of ingot, is known as the Gin and Leleux process, the largest installation of which

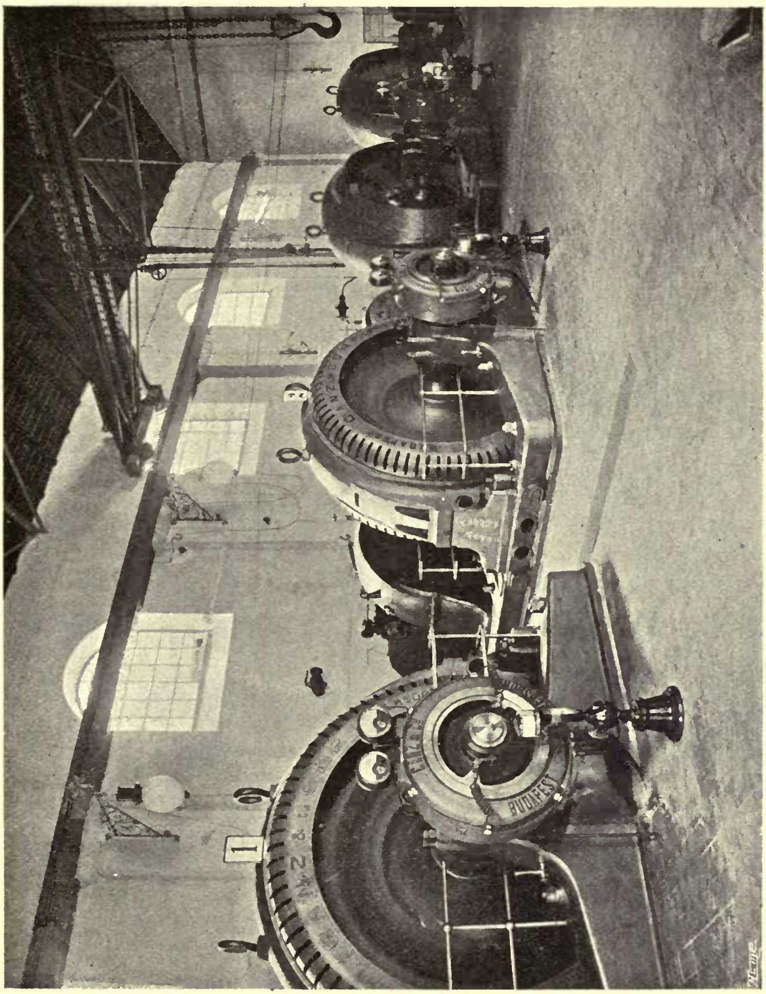


FIG. 83. THE MERAN DYNAMOS.

The Meran Works

is to be found at Meran in the Austrian Tyrol, where the water, collected in reservoirs near Partschins, is brought down to five turbines, which are of the Ganz type with automatic regulation. The generating installation consists of five alternating triphase machines

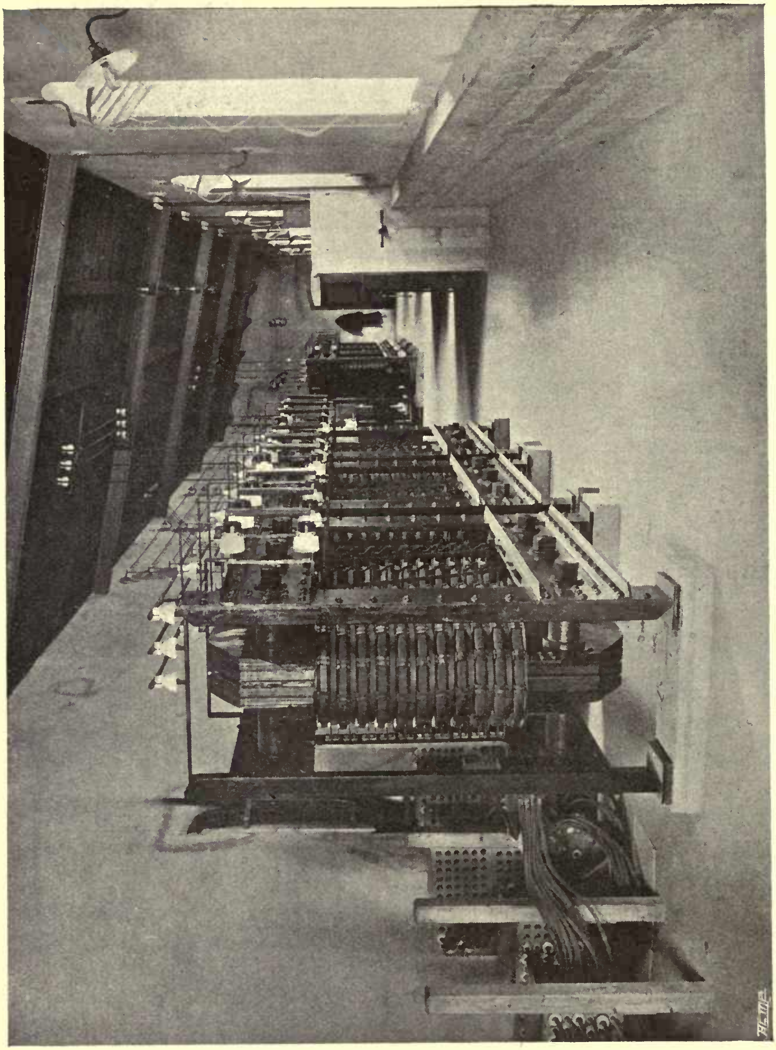


FIG. 84. THE TRANSFORMERS, MERAN.

of 1,200 H.P. coupled directly to the turbines and run at the rate of 320 revolutions per minute. Two of these machines supply light to the towns of Meran and Bouzen, whilst two others alternately coupled in

parallel furnish the necessary current for making the carbide, the fifth machine being held in reserve.

Meran transformers

The two generators actually employed in making the carbide furnish a total energy equal to 2,000 H.P., and the current is transported by a line of three conductors to the transformers. These consist of two groups of three transformers, having a power respectively of 260 kw. at a tension of 33 volts for use with the electric furnaces, secondly a group of three triphase transformers of 20 kw. at a tension of 310 volts, feeding the motors working the machinery, and thirdly a group of three triphase transformers of 8 kw. each, furnishing light at a tension of 110 volts.

The power used at Meran

The primary winding of each transformer of 260 kw. consists of three bobbins, coupled up in the form of a triangle; the secondary bobbins are coupled together in the form of a star, each furnishing a normal current of 2,500 ampères at 33 volts. Each furnace is fed simultaneously by a group of three transformers, the bobbins of the same phase being grouped in parallel with return, and the secondary insulation is arranged to keep down as far as possible the effects of mutal induction. All the transformers are by Messrs. Ganz, and are of very good construction, running continuously at a temperature of about 30° C. above the air temperature.

The electric furnaces employed were designed by Messrs. Gin & Leleux, and have a power of about 260 kw.; they are arranged longitudinally in batteries in a large building 40 metres long by 10 metres wide.

The Gin-Leleux furnaces

In this installation the question of continuous working has been overcome by dividing the furnaces into groups of two, so that whilst one is working the other can be cleaned out and refilled, one electrode being used for the two furnaces, so that when the operation has been completed in the one the electrode is moved over to the second. Each furnace consists of a crucible

mounted on a bogie. The casing is of $\frac{3}{8}$ inch sheet steel, pierced at the back and front with numerous

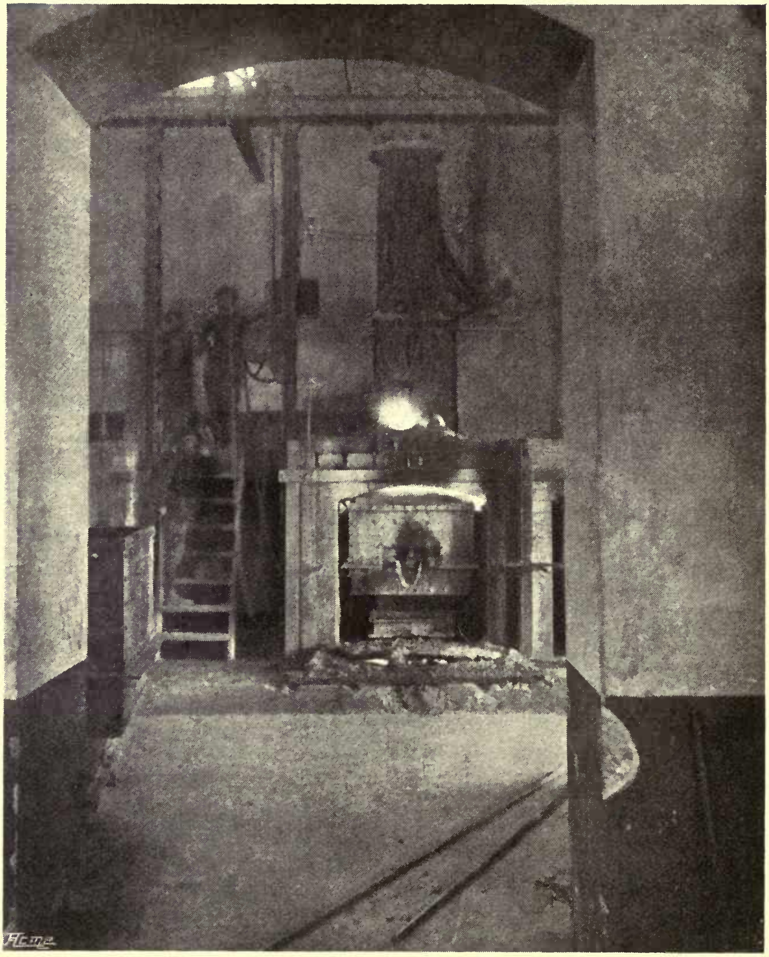


FIG. 85. AN ELECTRIC FURNACE AT MERAN.

The furnace bed

holes of about $\frac{3}{16}$ inch diameter to allow the escape of furnace gases. The bottom of the crucible consists of a thick cast-iron plate or sole, on the centre of which,

and in connection with it, are short blocks of electrode carbon bedded in a hearth of hard powdered anthracite. Level with the top of the hearth is the tapping hole from which the carbide is run in a liquid condition, the electrode carbons in the hearth being brought near to it in order to keep the carbide at this point as liquid as possible.

Conductors and crucible

The current is conducted to the crucible by cables clamped to a multiple contact plate attached to the sole of the furnace. This crucible having been run on rails under the brickwork arch of the furnace, the upper electrode can be lowered by well-arranged hoisting gear until an arc is struck with the bed of the crucible.

The upper electrodes

The upper electrode is built up of four Conradti carbons, each 130 cm. long and 20 cm. square. These are placed in a special mould and a mixture of powdered anthracite and tar is rammed around them to within 30 cm. of the top of the electrodes, and is then baked hard in a special furnace, yielding a solid electrode of about 60 cm. square with the four projecting heads of the Conradti carbons as an attachment for clamping to the electric cables.

Current employed

An alternating current is employed, and each furnace takes about 7,000 ampères and 33 volts, and in consequence of this low voltage the working is very steady and takes the minimum of regulation. In the Meran installation six furnaces are at work using about 1,300 kw. to 1,730 E.H.P.

The materials used

For making the carbide pure mountain limestone is obtained from quarries in the neighbourhood and brought to the works by a wire tramway, where it is burnt in a kiln by means of producer gas, with the result that a lime of great purity containing 98·76 per cent. of calcium oxide is obtained.[1]

[1] See analysis, p. 268.

Crushing and feeding the material to the furnace

The ingredients are fed into large jaw crushers, from which they fall through tooth roll machines into hoppers, supplying a revolving feed plate, by means of which the proportions of lime and coke in the carbide mixture can be exactly adjusted, and then passes through an automatic mixer to the furnace feed. The granulation and mixing of the ingredients exercise a considerable influence on the working of the furnace as, if not properly done, pockets form in the fused material, in which carbon monoxide collects and gives rise to dangerous spitting whilst running out the fused carbide. Nor is this the only inconvenience, as want of proper mixing renders the working of the furnace very irregular.

Troubles caused by bad mixing

The grinding and elevating machinery is made by J. Hopf, of Vienna, and works smoothly and well.

The working of the furnaces

The furnaces are run for three days at a time, the carbide being tapped from them at intervals of about two hours, the amount withdrawn becoming smaller as the outlet gradually becomes choked by deposits of carbide round the mouth of the tapping hole. This causes the gradual building up of an ingot within the crucible, and at the end of the third day the electrode is raised by the hoisting gear, run over the second furnace and lowered into position, the delay only amounting to from five to ten minutes. The crucible is then withdrawn from the first furnace, and the ingot extracted in the usual way.

The yield of carbide

The yield of carbide is 5·8 kilos per kilowatt day of a carbide generating 280 litres per kilo at 15° C. and 760 mm., equivalent to 5·1 kilos of a 320 litre carbide. The gases evolved during the working of the furnace are drawn off by a ventilator through lateral openings before they can reach the upper part of the furnace, so preventing overheating of the upper electrodes. This is done by fans which draw the gases and dust from the holes at the back of the crucible to a settling

Withdrawal of gases from the furnace

chamber, air at the same time being drawn in through the front holes.

In Italy the manufacture of calcium carbide has

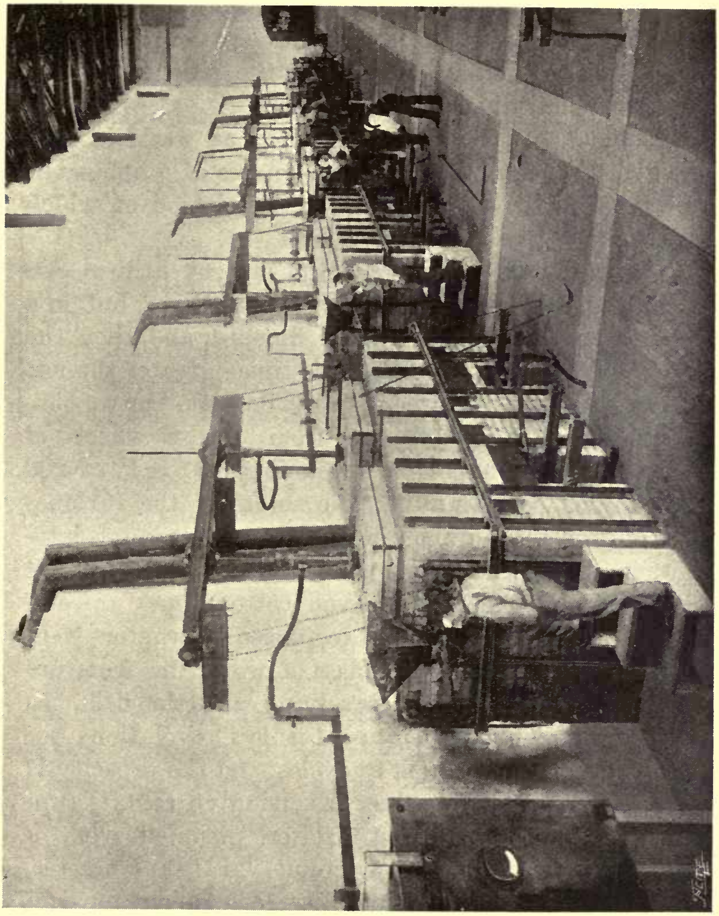


Fig. 86. The Furnaces at the Terni Works.

Calcium carbide manufacture in Italy

increased considerably within the last three years, and there are works at Pont San Martin, near Ivrea, whilst a carbide factory at Narni belongs to the Societa Italiana dei Forni Elettrici, of Rome, and the

Societa Italiana del Carburo de Calcio Gas Acetilene ed Altri Gas have large works near the Marmore Falls at Terni, where they utilise a 3,000 H.P. plant. A view of the furnaces of the Terni Company is shown in Fig. 86, and at these works not only do they run the carbide, but obtain it in so liquid a condition that it is cast into sticks, this being the only factory in the world in which this is done.

The Terni Works

A small carbide factory is also at work in San Marcello d'Aosta, and electric furnaces of a somewhat novel type are utilised there, a description of which appeared in the *Electrical World.*

The San Marcello Plant

The plant at San Marcello at present utilises 800 H.P. from the falls of the Dora Baltea River, but in a short time extensions will be finished, and then the plant will have a capacity three times greater than at present. Four Oerlikon 150 kilowatt three-phase alternators are rope-driven from the flywheels of horizontal turbines, each developing 400 H.P. at 200 revolutions per minute. The shafts of the turbines are on the same axial line, and may be coupled together by an elastic coupler. The diameter of the flywheels is 15 feet, and seven cotton ropes are employed for driving. The three-phase alternators were specially designed for this class of work, the armature is of the drum type and revolving, and the field has four poles. The normal speed is 480 revolutions per minute, the frequency is 16 cycles, and the capacity is 600 ampères at 146 volts. Exciting current is supplied by an independent exciter provided with a switchboard containing a circuit breaker, ammeter, voltmeter, and field rheostat. In each alternator field circuit is a resistance which may be controlled with great nicety. There is also an arrangement whereby the field current cannot be broken without first throwing in the whole resistance. The alternators are connected together mechanically and electrically two by

Description of the apparatus used

Arrangements for controlling the current

two, and whenever one of the alternators of a group needs repairing, it is possible to run the other one alone.

The Alternators

Each pair of alternators has a main switchboard panel of white marble, on which is grouped all the apparatus for the control and synchronising. Each panel has two ammeters, two voltmeters, and two three-phase switches. There are two pilot lamps for each alternator, connected across the leads for the control of the voltage, and a third lamp is used for synchronising. Since the alternators are mechanically coupled, a synchronising lamp seems superfluous; but this arrangement was provided to avoid a considerable difference of potential between the leads. In this latter case the synchronising lamp will blow, and the switchboard attendant be thus notified of the trouble. The ammeters are permanently in series with only one of the leads of each machine: this disposition is, of course, defective, for if it happens that one of the other phases is cut out at the furnace, the ammeter will not indicate the fact, and the switchboard attendant cannot judge of the work developed by the machine.

The conductors to the furnaces

From this switchboard the mains go to the furnace room, where there is another switchboard for the control of the furnace operation. On this switchboard are two 1,200 ampère switches and three ammeters. The conductors are tape insulated, and supported on paraffined wooden blocks, surrounded by an iron ribbon tightened with a bolt. The ends of the mains coming from the alternators are soldered to the cable terminals in the usual way, but the ends going to the furnaces have a special joint made with hard solder, since the heat conducted from the furnace in addition to the current-resistance heating would melt the ordinary solder. The cables in proximity to the furnaces are asbestos insulated.

The San Marcello or "Memmo" furnace

At San Marcello the arc type of furnace has been adopted. The arc is produced in a furnace either between a carbon block and a receptacle containing the material to be treated, or between the carbons. The heating produces the combinations required. Direct or alternating current may be used. Mr. Memmo, the engineer who installed and manages the plant, considers it more advantageous to use three-phase than single-phase alternating currents. There are then three arcs instead of one in the furnace, and the heating surface is thus larger and more uniform. The arcs may be developed either in a triangle between the carbons or in stars between the carbons and a conductive plate acting like the neutral point of the alternators. The control of furnaces using three-phase currents is very much simpler than in the case of other kinds, since, should one of the arcs blow out for any reason, the furnace will still operate on the other two arcs, and the strain on the alternators, due to sudden changes of load, is thus avoided.

The advantages of a triphase furnace

The continuous form of "Memmo" furnace

At San Marcello there are two different types of three-phase furnaces—continuous operation furnaces patented by Mr. Memmo, and furnaces operating intermittently. The general features of the first type are that they are cylindrical in shape, and made of refractory bricks. The three carbons are inclined and controlled by three threaded rods, each operated by a small wheel. For filling the furnace a metallic funnel is provided on top. A cast-iron plate, covered with several layers of graphite, may be lowered or raised the whole height of the furnace by means of a screw moved by a gear and pinion operated by a small wheel. In filling the furnace the material falls down between the carbons, the carbide is formed, and the plate is slowly lowered. After six or seven hours of work the plate is at the bottom, and it is possible to take off the carbide already cooled by a door provided

The working of the furnace

at the lower part of the furnace. The furnace may therefore work without intermission. The current during operation is controlled by lowering or raising the cast-iron plate, and the carbons are moved only when necessary to supply the loss caused by their consumption.

The intermittent "Memmo" furnace

The intermittently working three-phase furnace is of the greatest simplicity, and resembles in appearance the Willson furnace. Externally it has the shape of a cubical block, and the internal capacity is about 70 cubic feet. The walls inside are made of refractory bricks, and the outside of ordinary bricks. The bottom of the furnace, which is in contact with the melted carbide, is made of compressed bricks of magnesium oxide, or consists simply of a stratum of lime. The opening in front of the furnace is closed by refractory bricks, strengthened by an iron back, and is capable of being securely fixed to the furnace wall by means of iron bars. The furnace is covered by a refractory brick vault in which there are three holes for the three carbons. The front wall above the opening has a hole provided with a cast-iron pipe for filling the furnace while in operation. On the rear wall there is another hole similarly situated for the exit of the gas produced. The gas may either be burned as it leaves the furnace, and the products led away through a flue, or it may, after washing, be conducted to the baking furnace and there burned.

Construction of the furnace

The carbons used

The carbons are 5 inches in diameter, and held in a metallic carbon holder, secured to a large iron rod, which conducts the current and controls the position of the carbons. The iron rod is threaded its whole length, and screws up and down in a bronze collar, supported by a cast-iron plate considerably larger than the hole in the vault of the furnace. By turning the cylinder by means of a small wheel, it is possible

The system of control

to raise or lower the carbons in the furnace, and the control by this system is of great sensibility, as it avoids all sudden movements of the carbons, and makes it possible to gradually lower the carbons as the operation of the furnace requires. The leads are connected by bolts to the cast-iron plates.

The working of the furnace

In starting the operation the carbons are lowered to the bottom of the furnace, resting on a block of graphite or carbide, so as to be short-circuited at starting, the mixture of carbon and lime being an insulator. The furnace is then filled with briquettes of the mixture, and the internal dimensions of the furnace being considerable, there is always about half an inch of material next to the wall, which remains unchanged. It is well in practice not to remove this material, because it avoids excessive heating of the walls, and does not allow the melted carbide to adhere to them. When the furnace is filled, the door is shut and the fissures are filled with clay or lime. The filling pipe is closed with a metallic cover, which also acts as a safety valve, as the waste gases mixed with dust and air have a tendency to explode. The carbons being short-circuited, the switches are thrown and the alternators started. When at normal speed, the resistances in the armature circuit are gradually cut off. The speed then drops, and there is danger that the alternators may break down if the action of the turbine regulators is not quick enough, or when the water is not sufficient. When all the resistance is cut out, the normal current ought to be 1,200 per carbon at 145 volts. To regulate to this current the carbons are raised by means of the wheels until the current has its normal value. It sometimes happens that one carbon gives more current than the others owing to unequal distances, but the tendency disappears as soon as the first quantity of carbide is produced.

The current employed

In these furnaces the carbon employed is charcoal

from the forests, which are close to the works, the wood being transformed into charcoal in gas retorts, and the gas so made utilised for burning the lime. The material is then powdered and made up into briquettes with a little water and tar, which are then dried and baked after moulding. The material employed

The furnace is filled every fifteen minutes, it being necessary to keep it entirely full. To discharge the furnace it is necessary to stop the production. Each operation lasts from four to five hours. Having regard to efficiency, it would be more convenient to work more than five hours, as the production of carbide is larger during the last moments, and there would not be so great a loss of heat and usage of electrodes. But the troubles which occur after five hours of work are too frequent, and, besides, the quantity of gas produced is so large that it causes considerable inconvenience near the furnace. To stop the operation the alternator field is cut off, and the cables are taken out and connected to the next furnace, which has been prepared for working. Period of operation

Before discharging the furnace it is necessary to wait some hours to enable the carbide to solidify. The ingots weigh from 300 to 500 lbs., and require many hours to cool after they are taken from the furnace. When the blocks are of good quality, they are very hard to break. There are three different kinds of carbide, corresponding to different portions of the blocks. The carbide on the exterior of the block has the appearance of graphite. Inside it has a grey colour, and is partly crystalline. In the central portion of the block the carbide is crystalline, and has a red copper colour. This last kind gives the highest yield of acetylene. The carbide ingots Quality of ingot formed

In Spain at the present time there is only one carbide factory at work—at Montesquin; but several others are in course of construction, and it has been pointed out by Alexandre that the natural advantages The carbide industry in Spain.

of the country, as well as the high import duty on carbide, should render its manufacture lucrative.

The relative merits of the ingot and the run carbide processes

The reasons which led to the adoption of the running process in continental practice were that it was continuous, that the trouble of crust, inseparable from the ingot process, was done away with, and that a uniformity of quality was ensured, whilst the only apparent limit to the size of the furnace used was the size of the carbons obtainable. With the running furnace, moreover, the materials could be used in a coarser condition, and the dust nuisance in the factory reduced to a minimum.

The supporters of the ingot process, on the other hand, point out that the temperature needed to get the carbide to run in a satisfactory way without rapid clogging of the outlet is far higher than the temperature necessary to make the carbide, and for this reason so much more current has to be used that running furnaces can only be employed where power is cheap, and that the extra temperature so increases the wear and tear to the furnace that the cost of repairs becomes a most serious item.

The economic values of the two processes

As in most controversies of this character, many of the discrepancies disappear when the conditions are more carefully investigated. It is found in practice that the life of the running furnace is not appreciably less than that of the ingot crucible, and the price at which run carbide is made certainly does not suggest the use of excessive current. Further investigation shows that the whole question hinges on the quality of the carbide. If a standard were fixed for this of 320 litres per kilo, 5·08 cub. ft. per lb. at 0° C. and 760 mm., the running process could not compete with the ingot; whilst with a standard of 252 litres per kilo, 4 cub. ft. per lb., the running process could more than hold its own.

This is dependent on the fact that the temperature

of fusion of pure calcium carbide is about 3,000° C., and that in order to tap it from the furnace the temperature must not be less than 3,500, whilst even then the tapping holes soon clog and the waste of the furnace linings and electrodes becomes excessive. If, however, excess of lime be present, this acts as a flux, and causes fusion at a slightly lower temperature. Full advantage is taken of this by the manufacturer, and the result is that the run carbide is rarely of such high gas-yielding power as a good ingot carbide.

Run carbide

It is evident also that the efficiency of a furnace must to a great extent depend on the heat being as far as possible kept from escaping during working, and in the earlier forms of the ingot furnace this was entirely left to the mass of crude material surrounding the forming mass of carbide, and when the crucible, with its load of red-hot material, was drawn from the furnace and was allowed to cool, considerable loss of heat took place. In the running furnaces, also, considerable loss of heat takes place owing to the constant withdrawal of carbide at a temperature of about 3,000° C. The Deutschen Gold und Silber Scheide Anstalt of Frankfort have perfected an electric furnace for carbide making on the ingot system, which is a distinct advance, and if a high standard of carbide were insisted upon would undoubtedly be largely employed.

The conservation of heat in the Carbide furnace

The Frankfort furnace

The furnace consists of a square bottomless chamber of iron lined on the inner sides with magnesia bricks and at the top with fire bricks. The top is pierced to allow the upper electrode to pass in and also to admit the mouths of two hoppers from which the material is fed in and a tube to carry off the gases. Below the opening at the bottom of the furnace a small trolley can be run carrying a bed plate fitted with a hearth with conical sides in metallic connection with the bed plate and carrying the lower electrodes. The trolley having been run under the furnace is raised by chain

The construction of the Frankfort furnace

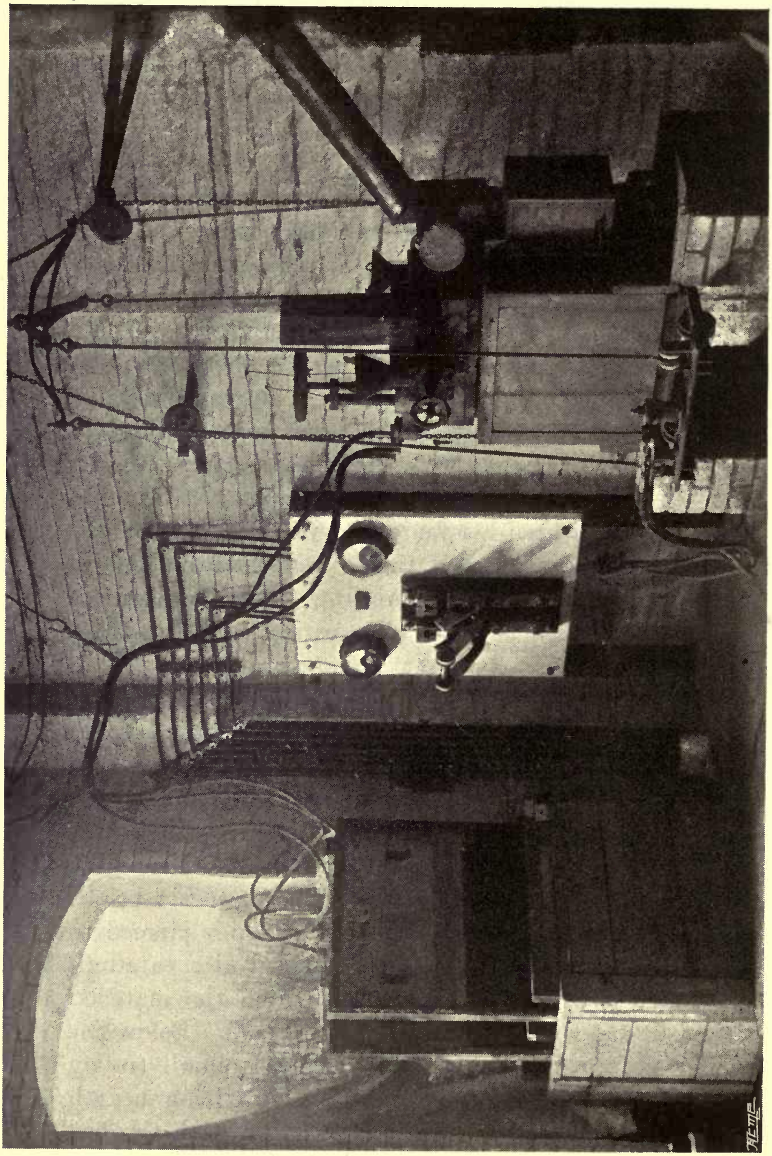


FIG. 87. THE FRANKFORT FURNACE.

gearing until the sloping sides of the hearth fit gas-tight into the bottom of the furnace. One cable is attached to the bed plate of the hearth by a multiple contact plate, whilst the other is in connection with the upper carbon carried in a sliding holder attached to a side guide, which allows exact regulation by means of a series of pulleys and hand-wheels. In the earlier furnaces made by the firm it was supposed to be necessary to grind the materials to a fine powder, and the form of furnace shown in Fig. 87 was used, the hot gases from the action, together with the dust carried with them, being removed through the broad tube seen on the right of the furnace. This type gave very good results, but it was a great improvement when it was found that fine grinding was unnecessary, and that the best results were obtained with the lime and coke about the size of peas, which entirely does away with the trouble existing with the old furnace

The connections

Condition of the material when introduced into the furnace

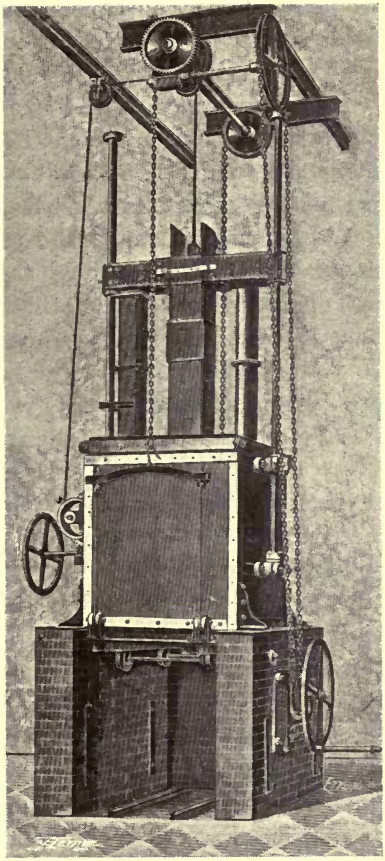


Fig. 88. The Latest Form of Frankfort Furnace.

Advantages of granulation

of the rush of hot gases sweeping out some of the lighter particles and upsetting the proportions of lime and carbon in the mixture.

The modern form of Frankfort furnace and its advantages

The advantage of this form of furnace is self-evident. Being enclosed, the carbon monoxide is, in the latest form, led away by a tube from the furnace crown, and is either discharged into the open air or is utilized in burning the lime. The upper carbon holder now runs on two guides instead of one, Fig. 88, making regulation more easy, whilst the great characteristic of the furnace is that, when the ingot has been built up within it, the hearth is lowered with the trolley and is run out, a new hearth being run in to take its place, in this way saving the heat stored in the furnace walls. The furnace works with 2,500 ampères at a tension of 50 to 75 volts, 60 to 65 giving the best results. The ingots are freed from crust and granulated to the required size by machinery made by Speyerer, of Berlin, which gives much less dust and waste than the ordinary crusher. These furnaces work very economically, making a ton of carbide from 1·6 to 1·7 tons of lime-coke mixture.

Output of the furnace

Method of working with the furnace

From the foregoing description it is seen that the working of the furnace might be made nearly continuous; but it is found better in practice to allow the ingot to slowly cool down to a certain extent in the furnace, as it is found that a larger yield of carbide is obtained. The explanation given is that as the semi-liquid ingot cools the heat converts the crust around it into true carbide; and it is quite probable that if there is any quantity of reduced calcium present, this will go on combining with the carbon present at temperatures far below that existing in the ingot when the current is cut off. The loss of heat from the escaping gases is not as great as might be expected, as they are rarely found to have a higher temperature than from 1,000 to 1,200° C., and it is

Temperature of the escaping gases

found that the storage of heat in the walls of the furnace lead to an increase in the output, the second make giving a better result than the first, the increase continuing until the maximum temperature of the walls have been reached. The make of carbide is slightly over 5 kilos per kw. day of carbide, yielding an average of 300 litres of acetylene per kilo.

Pre-heating furnaces

Several forms of furnace have been patented with the idea of raising the mixture of lime and carbon to the highest possible temperature before submitting it to the action of the arc, the idea being that by so doing a considerable economy in electrical energy would be gained; but it is at present still a somewhat open question as to whether much is to be gained, as the energy required to raise the materials through the first 1,500° is small as compared with that required for the last 2,000, and if the process necessitates much manipulation or costly furnace arrangements, the saving is swamped by the increased outlay.

General considerations

Crompton furnace

Crompton, in 1889, proposed preliminary heating for the materials to be subjected to fusion in the electric arc, and Reynolds designed a furnace which should embody this principle with continuity in action; whilst later, Pictet devised and patented a purely theoretical process in which the mixture of lime with excess of carbon is placed in a furnace chamber, in the upper part of which it is subjected to an air blast, and here the combustion of the excess of carbon is used to raise the temperature to about 2,000° C. As the mixture at this temperature falls in the furnace, it is played upon by oxyhydrogen blowpipe flames, which are expected to heat it to 2,400° C., at which temperature it is subjected to the electric arc and converted into carbide.

The early Pictet furnace

Drawbacks to the process

Such a process would be entirely impracticable on a manufacturing scale, as even supposing the theoretical temperatures could be attained at a price that

would render it commercially possible, the action of the air blast in burning out the carbon would destroy the uniformity of the mixture and would introduce such an excess of impurities owing to the ash from the carbon burnt away being left in the mixture, that if the carbide could be made it would be too impure to be marketable, whilst in experiments made by the author the formation of fusible silicates from the coke-ash and lime made the mixture "tacky" and stopped its downward passage to the arc.

Later modifications of the plant

Modifications of the process, however, might be employed by doing away with the internal combustion by the air blast and allowing the preliminary heating to be accomplished by the combustion of the carbon monoxide produced by the reduction in the electric arc—this of course taking place to a certain extent in every electric furnace.

The rationale of the process

Pictet's idea was to reach the high temperature necessary for the formation of calcium carbide from lime and carbon by a successive series of steps in the same way that the intense degree of cold necessary for the liquefaction of air is arrived at by a series of successive lowerings of temperature; but, as the idea came to be practically worked out, it became manifest that the cost of heating by special blast flames would be far too costly, and that if pre-heating were to be done, it must be by the utilization of the heat from the electric furnace and by the combustion of the carbon monoxide generated by the reduction of the lime by carbon; and plant has been erected at Ingleton upon this principle.

The Ingleton installation

It consists of two furnaces, one of which can be used as a "stand-by," and these work at 2,000 ampères. They are composed of an inner part or true furnace which is about 2 feet square by 3 feet high, built of bauxite bricks with an outer casing of ordinary firebricks. In the front of the furnace these two

Construction of the furnaces

layers of bricks are so spaced as to leave an open portion between the two, in which, before the furnace is started, a fire is lit in order to create a draught in the flue which surmounts the furnace.

Arrangement of the electrodes

The carbons for the arc are 6 inches square, and pass into the inner bauxite chamber, the negative carbon being inclined at an angle of 30°, whilst the positive carbon is horizontal and can be moved by means of a running screw, the carbon-holder, where it enters the furnace, being water-jacketed, whilst a second water-jacket is fitted round that portion of the holder to which the cable is attached, the water supply to these cooling devices being in separate insulated cisterns.

The working of the furnace

When the electric arc is struck, and acts upon the mixture of carbon and lime, the carbon monoxide that escapes from the furnace is led by a flue between the two lining walls and burns in the firebrick flues, which, passing up above the furnace, lead off at right angles. Inside this firebrick flue is an inner flue of iron, which, leading upwards from the furnace, passes from the outer flue at the bend and is continued to a floor above the furnace, where it is closed by a trap door, and acts as a feed down which the mixture of carbon and lime finds its way. It is manifest that this could not be done with an ordinary mixture of lime and carbon, as the strong draught would carry away a large proportion of the material, and so the lime and coke are compressed into small briquettes about two inches square, this being done partly to prevent the mixture becoming imperfect, and partly to prevent choking of the arc, as well as to allow a freer passage for the escape of the heated gases.

Briquettes of the mixture used

The Ingleton dynamo

The dynamo employed in this installation was of a somewhat novel form; its normal output is 2,000 ampères at 60 volts when running at 425 revolutions per minute. It was of the four-pole type, with cast

steel magnets and yoke. The armature was of the slotted drum type, with helical duplex winding, the armature inductors being of Crompton's patent compressed stranded cable. There are 68 sectors to the commutator and 68 inductors to each part of the duplex winding, and it was specially designed to run without sparking even when overloaded to the extent of 50 per cent.

This plant started working in 1898, but was not successful.

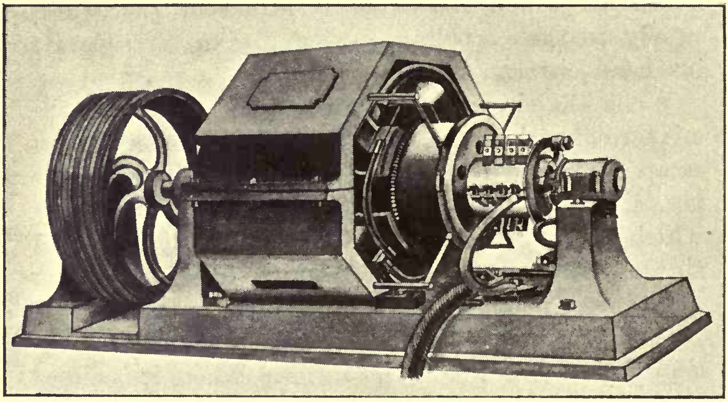


FIG. 89. THE INGLETON DYNAMO.

The Landin process

Another pre-heating process of the same character is that known as the "Landin" system, in which the powdered lime and carbon material—for which latter anthracite has been found excellent—with a small percentage of tar, are formed under high pressure into briquettes, which are heated up to 400 to 500° C., when they change their appearance and form a hard, uniformly caked mass. The hydrocarbons distilled off are condensed and used again for mixing with a fresh portion of lime and carbon.

The manufacture of briquettes of

The briquettes then contain calcium and carbon in the theoretical proportions required for the carbide

reaction, and are then further heated to white heat in the upper portion of the carbide furnace, after which they are brought between the electrodes and into the arc, where they are melted and form carbide. Experiments have shown that the briquettes heated even to 2,200° C.—the temperature being measured by the thermophone of Professor J. G. Wiborg, of the Technical High College at Stockholm—do not change their form, physical properties, or chemical composition in the absence of air. They, therefore, reach the electric arc in a highly-heated state and of the exact composition required. The pre-heating is done in a specially-constructed furnace, where the briquettes pass through a separate channel heated from the outside, and from which air is excluded, the carbon monoxide from the electric furnace being utilised to supply the necessary heat.

lime and carbon

The construction of the Landin furnace

In order to further facilitate the reaction and lower the necessary temperature of carbide formation a small quantity of calcium chloride or fluoride is mixed with the briquette materials, which melts, and in the arc is dissociated into calcium and chlorine, the calcium in the nascent condition combining with carbon to form carbide, and the chlorine in the comparatively cooler parts of the furnace reacting on the calcium oxide re-forming calcium chloride, etc. (CaO—132 calories. $CaCl_2$—170 calories), so that the process may be said to be electrochemical as compared with the hitherto exclusively thermoelectrical methods used. That the calcium chloride does not evaporate without action is shown by traces of it having been found in the carbide.

The Landin process an electrochemical one

It is interesting to reproduce the theoretical considerations upon which Landin bases his process, as it gives an idea of the margin of gain expected. "The importance of a good pre-heating of the raw materials before their treatment in the electric arc is shown

The theoretical considerations on which Landin bases his process

by the following comparative calculations of the quantities of carbide produced by 1 E.H.P. in twenty-four hours with and without pre-heating. Of course such theoretical calculations are not exact, as they do not take into consideration the changes of the specific heat with the temperature, etc., but when made fully comparative they always have a good deal of value.

Specific heat of calcium oxide 0·2, and of carbon 0·45. Heat of formation of calcium carbide from free calcium and carbon left out of calculation, as of no importance. The temperature of the reaction is taken as 3,000° C.

Calorific considerations

"1. Without any pre-heating.	cal.
Heating 56 grams CaO to 3,000° C.—3,000 × 0·2 × 56/1,000 = ...	33·6
Heating 36 grams C to 3,000° C.—3,000 × 0·45/36/1,000 = ...	48·6
Dissociation of CaO	132·0
	214·2
From which are to be subtracted—which are given off by the formation of CO	28·8
Necessary for 64 grams of CaC_2 . . .	185·4
"2. Pre-heating the raw materials to 1,500° C.	
Heating 56 grams CaO from 1,500 to 3,000° C. .	16·8
Heating 36 grams C from 1,500 to 3,000° C. .	24·3
Dissociation of CaO	132·0
	173·1
From which are to be subtracted.	28·8
Necessary for 64 grams CaC_2	144·3
"3. Pre-heating the raw materials to 2,000° C.	
Heating 56 grams CaO from 2,000 to 3,000° C. .	11·2
Heating 36 grams C from 2,000 to 3,000° C. .	16·2
Dissociation of CaO	132·0
	159·4
From which are to be subtracted.	28·8
Necessary for 64 grams CaC_2	130·6

"Thus there are required for 64 grams carbide in 1, 185·4; in 2, 144·3; and in 3, 130·6 calories. If 1 E.H.P. is put to, say, 550 calories per hour, we obtain from 1 E.H.P. in 24 hours, in 1, 4·55 kilos.; in 2, 5·85 kilos.; and in 3, 6·47 kilos. of carbide, which comparative figures fully show the importance of the pre-heating. If the temperature of formation of the carbide is taken at 2,700° C., the corresponding figures will be as follows:—for 64 grams carbide, 1, 177·18; 2, 136·08; and 3, 122·38 calories; or for 1 E.H.P. in 24 hours, 1, 4·77; 2, 6·21; and 3, 6·50 kilos. of carbide.

Amount of Carbide formed per E.H.P. per 24 hours for different degrees of pre-heating

It must also be remembered that most of the heat required can be obtained from the carbon monoxide formed by the carbide reaction. For the pre-heating of the raw materials for 64 grams carbide to 2,000° C. there are theoretically required 54·8 calories (compare above), but for 64 grams of carbide there are found 28 grams of carbon monoxide, which in burning to carbonic acid will give rise to 69·16 calories, consequently theoretically more than required."

Utilization of the Carbon-monoxide for pre-heating

Such a calculation as this, as Landin points out, is open to many errors, owing to our want of knowledge of the alterations in specific heats, etc., at high temperatures, whilst it can only be approximately comparative owing to unavoidable loss of heat during the working of the furnace owing to radiation, conduction, absorption of heat by the furnace, and other practical factors of the same character.

It must also be remembered that "pre-heating" is only a question of degree, as in every form of furnace the radiation from the neighbourhood of the arc and the escape of the hot gases will heat the material before it reaches the arc and comes under the direct influence of the electric discharge. It is interesting, therefore, to note what ratio exists between the results obtained in actual practical working and Landin's theoretical figures.

Pre-heating only a question of degree

The practical working of an ingot furnace as contrasted with Landin's figures

At Foyers, working with the Willson furnace and the improved crucibles, the average consumption of energy is 5,600 E.H.P. hours per ton of carbide of an average quality of 5 c. ft. of acetylene per lb., and this is equivalent to 4·2 kilos. per E.H.P. per day of 24 hours, or 5·5 kilos. of 90 per cent. carbide per kilowatt day. The calculation is based on pure calcium carbide, and, therefore, 10 per cent. must be deducted from the 4·2 kilos. reducing it to 3·78 kilos. per E.H.P. per day, as against the calculated 4·55, a loss of nearly 20 per cent.

The first degree of "pre-heating" taken by Landin is 1,500° C., and it is very doubtful if in practical working this could be reached—it certainly would not be exceeded—and, with the briquettes heated to this temperature before the arc is reached, it is calculated that 5·85 kilos. per E.H.P. per 24 hours would be produced; deducting from this the 20 per cent. for unavoidable furnace losses we obtained 4·63 kilos. of carbide per E.H.P. per 24 hours, an increase of not quite 24 per cent.

Patin furnace

Patin uses a furnace with inclined electrodes, and a movable bottom below them on which the carbide ingot is built up, the bottom or hearth descending as the ingot increases in size, instead of as in the ordinary ingot furnace, the upper electrode being raised. This makes the furnace rather more complicated than the ordinary type, but there is the distinct advantage that dust is minimised, and, as very little air can reach the carbons, waste from burning is reduced.

Borchers' proposed new carbide furnace

Borchers has proposed a form of electric furnace designed to obviate the waste of material as dust, the loss of carbide due to cooling in air and waste heat. It consists of a smelting chamber, with thin walls enclosed in a water jacket. The finished block of carbide is left for several hours in the furnace, and the heat

which it gives out is utilised for steam generation. By working a series of such furnaces at intervals of two hours or less, he claims that a constant supply of heat for steam generation can be obtained.

General details of the process

The carbon required for the formation of carbide is supplied by the electrodes, and the lime is used in the form of lumps, not in a fine powder. When the necessary heat has been attained within the furnace, the lime around the electrodes unites with them to form carbide, and this latter flows away in a fused state. The size of the furnace and the charge of lime are so adjusted that the sides of the smelting chamber are always protected by a layer of unused lime from the action of the intense heat at the centre. The system can be used with either arc or resistance furnaces. Borchers claims for these furnaces that by their use one-fourth of the power hitherto used in carbide production can be saved.

Claims made for the process

Novel as the idea undoubtedly is, it seems very improbable that it could ever prove commercially successful, as a consideration of the price of electrode carbon, as compared with the coke or anthracite usually employed, at once shows that the process would not be feasible.

Many other forms of electric furnace have been suggested and patented during the past few years, but those described give a fair idea of the working possibilities of the process of carbide making, and practical men are becoming more and more convinced that simplicity and freedom from complicated working parts likely to get out of order at the high temperatures employed, is, after all, the great end to be attained.

CHAPTER VI

THE MANUFACTURE, PROPERTIES, AND IMPURITIES OF CALCIUM CARBIDE

Crude materials for Calcium Carbide manufacture

NO matter the form of electric furnace employed, the crude material used for the manufacture of the carbide is in all cases lime or calcium oxide, and carbon in the densest and purest form obtainable in the locality where the carbide works are situated. In the first two years of the carbide manufacture but little attention was paid to the purity of the ingredients employed, and it was not until the extended use of acetylene drew attention to the fact that its combustion in a small room gave rise to a distinct haze in the air, and that occasionally a sample of bad carbide would yield a spontaneously inflammable gas, that the necessity of using lime and carbon of the highest attainable degree of purity was realized, as it was manifest that the traces of phosphuretted hydrogen that gave rise to these troubles must have been generated from phosphides decomposable by water in the carbide, and that these were formed by the reduction of phosphates present in the lime or in the ash of the carbon used. As soon as this point had been clearly demonstrated, attention was paid to the purity of the ingredients, with the result that acetylene made at the present time rarely contains one-tenth the amount of phosphuretted hydrogen that was

Importance of purity in the materials used

Causes of Phosphuretted Hydrogen in crude Acetylene

found in the acetylene made from carbides manufactured in 1896 and the early part of 1897.

Lime

Lime or calcium oxide, CaO, is a compound containing:—

Calcium	71·4
Oxygen	28·6
	100·0

Carbonates of Lime

and is commercially produced by heating calcium carbonate, $CaCO_3$, in a kiln, when carbon dioxide is expelled from the compound and lime remains as the residue.

The forms in which the carbonate is found are very numerous. In the amorphous state it exists as limestone and chalk: the crystalline forms being calc-spar or Iceland spar, and arragonite. Marble has also a crystalline form, and sometimes is found coloured or variegated by the presence of oxides of iron and manganese. Black marble owes its colour to the presence of bituminous matter. Calcium carbonate is also the principal constituent of egg-shells, the shells of fishes, and coral.

All forms of calcium carbonate decompose when heated, splitting up into calcium oxide or lime and carbon dioxide gas:—

$$\underset{\text{Marble.}}{CaCO_3} = \underset{\text{Lime.}}{CaO} + \underset{\text{Carbon dioxide.}}{CO_2}$$

Conversion of the Carbonates into Lime

This process is carried out on an enormous scale for the preparation of calcium oxide or quicklime for manufacturing and building purposes, by heating limestone by means of layers of fuel in a kiln, which consists of a conical brick building. The limestone loses its carbon dioxide, and is raked out in the form of burnt- or quick-lime.

Kilns for burning the Lime for Carbide

The ordinary method of kiln burning for the production of lime is inadmissible when that compound is required for carbide making, as the presence of the ash from the fuel used adds so largely to

the impurities derived from the calcium carbonate that a bad carbide is sure to result, and in all good carbide works the lime employed is burnt in gas kilns in which the heat is derived from the combustion of producer, Dowson, or water gas.

Thorough burning and freshness essential

The lime for carbide making should be more thoroughly burnt than for ordinary use, and should be used fresh, as if it has taken up moisture or carbon dioxide to the extent of more than 2 per cent., it begins to affect the yield of carbide in the furnace.

Qualities needed in Lime for Carbide

The choice of a site for carbide works is of course primarily dependent on the cost of power at that particular place, but the presence of pure calcium carbonate within easy reach is an important factor. In determining the fitness of a lime supply for carbide making, the chief consideration is the absence of phosphates, and the presence of at most only small traces of magnesium and aluminium with as little silica as possible.

Impurities to be avoided

Some carbide makers lay great stress on the absence of sulphates from the lime, but in the absence of aluminium the presence of sulphates in small quantities is of no importance, as unless aluminium sulphide is formed in the carbide it will not find its way into the acetylene as sulphuretted hydrogen in any large quantity.

Variation of impurities with different forms of Carbonate of Lime

The impurities in the calcic carbonate vary very much with its form, the crystalline carbonates, Iceland spar and arragonite, being practically pure, marble containing but few objectionable impurities, whilst the amorphous limestones and chalk are often too impure for use, and will vary in different parts of the same deposit.

Chalk and its impurities

Chalk is in many parts of the world the most abundant form of calcium carbonate, and may be of fair quality, as is shown by the following analyses from the same deposit :—

	Lower deposit.	Upper deposit.
Calcium carbonate	96·51	97·20
Oxides of iron and alumina	0·55	1·05
Magnesia	0·25	0·06
Phosphoric acid	0·07	0·04
Sulphuric acid	0·31	trace
Potash	0·08	0·17
Soda	0·19	0·02
Insoluble matter—silica	2·04	1·46
	100·00	100·00

Limestone

The various forms of limestone vary very much in purity, those from the older geological series being generally more impure and containing less calcium carbonate than those of later date.

The older forms show a high percentage of silica and phosphoric acid, such samples being of course useless as a source of lime for carbide making.

The newer formations are far purer :—

Analysis of Limestones

	Oolite Limestone.		Corn-brash.	Mountain Lime-stone.
	1	2		
Calcium carbonate	93·91	95·34	89·19	96·35
Oxides of iron and alumina	0·98	1·42	2·98	0·67
Magnesia	0·73	0·73	0·77	2·28
Phosphoric acid	0·14	0·12	0·18	trace
Calcium sulphate	1·34	0·20	0·24	*nil*
Moisture	1·46	—	—	—
Silica, etc.	1·44	2·19	6·64	0·7
	100·00	100·00	100·00	100·00

Mountain Limestone

Many of the mountain limestones are clearly akin to marble, and amongst these are found some of the finest material for carbide making, an analysis of a sample lately made yielding :—

Calcium carbonate	99·90
Calcium sulphate	trace
Magnesium carbonate	0·02
Iron carbonate	0·04
Silica	0·02
Phosphates	*nil*
	99·98

And it is manifest that no finer source of lime than this could be desired. In Norway very pure limestone is obtainable, and will prove of great value to the carbide industry that is rapidly springing up around the centres of water power, whilst the lime used at many European works is obtained from mountain limestone of great purity.

Analyses of Lime used at Continental Carbide works

ANALYSES OF LIMES USED FOR CARBIDE.

Works.	Hafslund.	Meran.	Rheinfelden.	Froges.
Lime	94·560	98·76	93·36	95·64
Magnesia . . .	1·180	0·09	0·01	trace
Silica	1·030	0·99	0·31	1·69
Iron and Alumina .	0·530	0·02	0·27	1·51
Phosphorus Pentoxide	0·048	*nil*	trace	*nil*
Sulphur Trioxide .	0·128	*nil*	0·12	0 46
Carbon Dioxide and Moisture . . .	2·524	0·14	5·93	0·70
	100·000	100·00	100·00	100·00

Concentration of the impurities from the material in the Carbide

It must be clearly borne in mind that although the percentage of impurities present in the materials may appear so minute as to be totally negligible, yet they undergo a process of concentration in the manufacture of the carbide that may have a distinct effect upon the acetylene generated from it.

One hundred parts by weight of calcium carbonate when burnt yield 56 parts of lime, and as the heating has practically no effect upon the impurities, this at once nearly doubles them in quantity, whilst no matter what the form of carbon used it will alway

contain several per cent. of ash, which consists of very similar constituents to the impurities of the lime. Under the best conditions the mixture of lime and carbon can only yield a little under two-thirds of its weight of carbide, whilst even the intense heat of the arc and the reducing actions taking place only lower the percentage of the impurities in about the same ratio, so that it is evident that it is useless to employ anything but the purest materials if the carbide is required of good quality. This is now thoroughly recognised, and more than one works employ lime containing nearly 99 per cent. of calcium oxide.

Carbon for Carbide making

The carbon employed at the present time in making the carbide mixture is either coke, anthracite, or charcoal.

Coal

Coal is a compound now ascertained to be of entirely vegetable origin, and is the remains of a vegetation which covered the land long before it was inhabited by man. This vegetation has undergone partial decomposition, and has been covered by accumulations of clay and sand, the pressure of these deep overlying strata has prevented the evolution of gas, and has destroyed most traces of vegetable structure and given to the pit coal its close and compact form; but ample proof of its origin is to be found in the fossil remains of upwards of five hundred different kinds of mosses and ferns, whilst in the layer immediately below the seam fossil roots are found in abundance.

Origin of Coal

The different classes of Coal

The three principal varieties of coal are lignite, bituminous coal, and anthracite, the lignite or brown coal being the least carbonised, showing indications of organised structures, and containing considerable proportions of hydrogen and oxygen; whilst anthracite is the most carbonised and often contains little else than the carbon and the mineral matter or ash.

The conversion of woody fibre into Coal

When moist vegetable matter undergoes fermentation and decay, carbon dioxide and marsh gas are the gaseous compounds which escape, and it is easily conceivable that the final action taking place during long ages, aided by pressure and the internal heat of the earth, is the conversion of woody fibre into carbon in the dense form known to us as graphite; whilst intermediate steps in the decomposition give us peat, lignite, bituminous coal, and anthracite. The complete reaction could be represented by the equation :—

$$\underset{\text{Woody fibre.}}{2(C_6H_{10}O_5)} = \underset{\text{Carbon dioxide.}}{5CO_2} + \underset{\text{Marsh gas.}}{5CH_4} + \underset{\text{Carbon.}}{2C}$$

which is supported by the fact that these two gases are always found in the coal seams. The theory that bituminous coal is a "younger coal" than anthracite is not, however, borne out by the fact that in the eastern part of Wales the coal is of a bituminous nature, gradually shading away into the anthracite found in the western portion of the Principality, and it is extremely unlikely that there is any very great difference in the age of the different parts of the Welsh coal field.

The changes taking place in the conversion of woody fibre into Coal

The gradual conversion of woody fibre into peat, coal, and graphite is illustrated by the following table (Percy), in which to show the gradual elimination of hydrogen and oxygen the carbon is kept as a constant number :—

	Carbon.	Hydrogen.	Oxygen.
Wood	100	12·18	88·07
Peat	100	9·85	55·67
Lignite	100	8·37	42·42
Bituminous coal . .	100	6·12	21·23
Anthracite—Wales .	100	4·75	5·28
„ Pennsylvania .	100	2·84	1·74
Graphite . . .	100	0·00	0·00

It will be seen from this that coal contains very different quantities of bituminous matter which varies with the state of conversion to which it has attained, lignite and cannel coal containing a large quantity of hydrogen, which as soon as the coal is heated becomes converted with some of the carbon into tarry matter and then into inflammable gases. Bituminous coals, like Wallsend and Silkstone, also contain hydrogen to a large extent, and it is from this class of coal that those used in the manufacture of illuminating gas are selected, whilst when one reaches anthracite the natural elimination of gaseous matter has proceeded so far that the volatile matters that can be gasified have been reduced to a very small percentage.

The quantity of Bituminous matter in Coal

Gas Coal

Anthracite

When making carbide it is only this last kind of coal that could be employed, as if a bituminous coal were selected tarry matter distilling out would cause a caking of the mass and prevent the flow of material to the electrodes, whilst the carbon monoxide evolved by the interaction taking place in the arc would be so augmented by the gas evolved from the coal as to cause serious "blows" in the mixed materials, and probably dangerous explosions in the upper part of the furnace.

Reasons for not using Bituminous Coal for Carbide

The amount of ash present in anthracite is comparatively low, and with good samples of this material, such as can readily be obtained in South Wales, the ash often does not exceed 2 per cent., and inasmuch as anthracite culm can be obtained very cheaply, it is now being very largely employed in the manufacture of carbide. The following table shows the composition of some of the best Welsh anthracites :—

Composition of Anthracite from South Wales

South Wales Anthracite.

Description and Locality of Coal Beds.		Carbon.	Bitumen Volatile Matter	Ashes or Cinders.
Ystal-y-fera Ironworks, Swansea Valley	Big vein, 1st vein	91·42	7·08	1·50
	" 2nd "	92·89	5·61	1·50
	" 3rd "	91·99	6·51	1·50
	Cefn vein, upper bed	91·26	7·24	1·50
	" lower part	91·89	6·61	1·50
	Brass vein, upper part	92·46	6·04	1·50
	" lower "	91·52	6·98	1·50
	Black vein	93·14	5·36	1·50
	Little vein	90·64	7·86	1·50
	Pentrych wynn	95·69	2·81	1·50
Cwm Neath	Three-feet vein	94·10	4·90	0·93
	Eighteen-feet vein	91·43	6·24	2·28
	Nine-feet vein	93·12	5·22	1·59

Coke

During the early years of the carbide manufacture coke was almost exclusively used as the source of carbon, and is still extensively employed, a good metallurgical coke being excellent for the purpose.

It has already been pointed out that the ordinary bituminous coals, and the brown coals, or lignites, could not be used for making carbide, but if the bituminous coal be heated to high temperature out of contact with air, the volatile portions are driven off as gaseous and liquid products, whilst the excess of carbon and the mineral matters which form the ash are left behind in the form of coke.

Coking Coal

It is not possible to make a good coke from very bituminous coal, like lignite or cannel, nor can it be made from coals too poor in volatile matter, such as anthracite, but given an ordinary bituminous coal, such as abounds in the Newcastle and Durham districts, a hard metallic coke can be produced from it.

Coke is either made as a bye-product in the manufacture of gas, or else is specially prepared for metallurgical work in coke ovens.

In making coal gas, the raw coal is taken in pieces, which vary in size from dust to large lumps, and is carbonised in retorts at a temperature of 1,000° C., the operation of driving off the volatile constituents being stopped before completion, as the last portions of gas evolved are so low in illuminating power that if the coke were heated until all the volatile matter was driven out the illuminating value of the gas would be deteriorated, whilst sulphur compounds would appear in the gas in undue proportion. The result is that the coke so made still contains some volatile matter, and a considerable proportion of the sulphur present in the original coal. It is dull in appearance, friable, and soft, and is rarely pure enough to be used for carbide making, often containing a considerable proportion of earthy matter, due to the coal having been used in a "dirty" condition. **Gas Coke** **Gas Coke unfitted for Carbide making**

Furnace or metallurgical coke, on the other hand, is specially prepared in chambers, known as coke-ovens, of which many modifications exist. For this purpose selected coal is crushed, and after screening is washed, so as to cleanse it from dust and minerals which vary from it in specific gravity, the powdered coal being afterwards converted into coke in the ovens, with the result that earthy matter and pyrites rich in sulphur are, to a considerable extent, got rid of. The coke so produced is far purer than is the case with gas coke, and the temperature employed for the carbonisation being considerably higher, the coke left behind is harder and less friable. **Metallurgical Coke** **Preparation of Coal for Coking**

Metallurgical coke varies a good deal in appearance, but generally has a bright surface, and when struck an almost metallic ring. Good coke should show a silver-white or light-grey colour when in lump, and when reduced to powder should be dark-grey or black. It is not safe, however, to draw any conclusions as to the quality of the coke from its colour, as the silvery **Physical properties of good Coke**

lustre is very often absent from coke which has been made in ovens so constructed as to collect the bye-products, a dulling of the surface being brought about by the hydrocarbon gases as they escape from the coal being kept for a short period in contact with the hot surface, and depositing some of their carbon in an amorphous condition on the surface, whilst with ovens, in which the bye-products are simply burnt off, a trace of air generally gains access, and prevents the separation of amorphous carbon, the coke then showing a characteristic silvery appearance. It is often found, too, that the appearance of a coke is spoiled by quenching it with water containing much soluble matter, which, leaving a film of residue on the surface of the coke, deteriorates its appearance.

Appearance of Oven Coke

Ash in Coke

The amount of ash present in coke varies with the composition of the coal from which it was made, and the following table of analyses gives an idea of the amount of variation which may occur in the carbon, ash, and sulphur:—

Composition of Coke

Carbon . .	95·51	85·85	90·53	94·21	93.41	93·05	89.87
Ash . . .	2·85	12·07	8·46	5·10	5·80	5·37	8·35
Sulphur . .	1·64	2·08	1·01	0·69	0·79	1·58	1·78
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Carbon . .	84·82	96·42	97·60	94·08	92·44	89·69
Ash . . .	14·40	2·75	1·55	5·04	6·00	8·35
Sulphur . .	0·78	0.83	0·85	0·88	1·56	1·96
	100·00	100·00	100·00	100·00	100·00	100·00

Carbon . .	91·16	93·54	91·49	94·31	94·67	92·70
Ash . . .	7·65	5·70	7·05	4·97	4·26	5·70
Sulphur . .	1·19	0·76	1·46	0·72	1·07	1·60
	100·00	100·00	100·00	100·00	100·00	100·00

Composition of the ash of Coke

The ash left by coke closely corresponds to the composition of the ash of coal from which it was formed, although the proportions of sulphur and water of hydration present in some compounds in the

coal ash are driven off during the process of coking, and the high temperature of the coke oven will bring about a certain amount of decomposition and recombination between the mineral substances of the coal. Thus the calcium and magnesium, which are found as carbonates in the coal, are broken up into lime and magnesia during the process of coking, and these combine with the silica present, so that in the coke ash they would be found as silicates of calcium and magnesium, instead of as the original compounds.

Analyses of typical Coke

In the ash both of coal and of coke silicic acid or silica, alumina, oxide of iron, lime, magnesia, sulphur, and phosphorus form the chief constituents, and the following table (see page 276), compiled from the work of various analysts, gives a good idea of the proportions in which they are present.

Sulphur in Coke

The sulphur may be present either as the double sulphide of iron and copper, known as pyrites, calcium sulphate, or gypsum, while a small quantity is also probably combined with carbon, hydrogen, and oxygen; the original source from which the sulphur was derived being the plants which formed the coal measures, and in which sulphur played a far more important part than in the vegetation of the present age.

The source of the Sulphur and Phosphorus in Coke

The phosphorus is obtained from the same source, M. Carnot[1] stating that it is principally derived from spores and pollen grains, which are easily observable under the microscope in the accumulations of decomposed vegetable matter, whilst the silica, alumina, oxide of iron, lime, and magnesia, which go to make up the mineral constituents of the ash, have been derived either from the sap of the original plant, or the soil surrounding the coal measures.

Wood Charcoal

In some few parts of the world the difficulty of obtaining anthracite or good metallurgical coke has led to attention being paid to the possibility of utilising

[1] *Compt. Rendu*, 99, 154.

COMPOSITION OF ASH FROM COKE.

Coke from	Silica.	Iron Oxide.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Other Constituents.
Neunkirchen, Rgbzk, Trier	44·43	14·2	34·92	2·2	2·09	not determined	not determined	2·16
Königin Marienhütte, Saxony	41·2	28·0	17·40	8·0	1·66	2·05	·164	1.526
" " Planitz	44·66	19·08	20·53	4·45	1·63	2·26	·257	7·133
" " Wilhelm pit	44·60	18·06	22·13	5·84	1·63	2·70	·129	4·911
Dortmund Union, Consolidation	41·96	19·05	27·01	·97	·89	·36	·361	9·399
" " Barop	26·79	26·79	21·04	5·89	4·10	not determined	·18	15·21
" " Manseld	40·63	18·23	26·70	3·67	3·12	—	·14	7·51
Hörder Iron Works	40·0	18·6	30·0	2·60	1·30	—	·22	7·28
Terrenoir, Carvès ovens at Bessèges	43·66	11·75	26·90	9·65	1·90	2·0	·087	4·053
Upper Silesian	14·03	21·32	8.94	19·95	10·0	1·01	2·09	14·66
Grand 'Combe	51·5	10·4	24·4	7·80	2·0	·66	·057	5·183
Trelys	49·0	7·3	29·0	8·2	2·05	·47	·052	3·928
Molierès	48·0	7·3	26·0	14.6	3·70	·40	·070	—
Aniche Dechy	48·5	7·9	33·7	2·0	3·70	·04	·30	3·86
Grand Bouillon	43·4	17·98	23·8	4·98	3·70	·13	·09	5·92
Aubin	50·0	8·0	32·0	5·0	3·70	·67	·08	·55
Dowlais	24·18	16·00	20·8	9·4	9·7	1·4	·052	18·468
"	39·68	7·5	39·2	1·8	2·6	traces	·57	8·45
Anthracite, Pennsylvania	43·70	6·0	39·3	5·7	3·0	—	·57	1·73
Douchy	47·0	11·5	29·74	4·40	1·72	·74	·20	4·70
Connellsville	56·73	5·1	34·74	2·5	·74	not determined	·42	—

other forms of carbon, and where wood is abundant charcoal has been employed. A well-burnt wood charcoal contains, as a rule, between 2 or 3 per cent. of ash, and is practically free from sulphur. The following analytical results obtained by Faisst[1] give an idea of the composition:—

Analyses of Charcoal

	Beech charcoal.	Hard charcoal made in iron cylinders.	Light charcoal from wood-gasworks.
Carbon . . .	85·89	85·18	87·43
Hydrogen . . .	2·41	2·88	2·26
Oxygen and Nitrogen	1·45	3·44	0·54
Ash	3·02	2·46	1·56
Water. . . .	7·23	6·04	8·21
	100·00	100·00	100·00

Phosphorus in Wood Charcoal

A well-burnt specimen of charcoal contains, as has been stated, practically no sulphur, but it generally contains very considerable traces of phosphates, which unfit it for making a good carbide.

Patera, Ackermann, and Saernstroem in considering the value of charcoal for metallurgical purposes have drawn attention to the quantity of phosphorus present in the ashes of various woods, which are about as follows:—

Wood.	Ash.	Percentage of phosphorus in charcoal.
Beech	2·97	0·1485
Pine and Fir . . .	2·15	0·1078
Scotch Fir	1·99	0·0995

Influence of the temperature of Carbonising on the Charcoal found

In charcoal the ratio of carbon to ash and also to gaseous constituents varies with the temperature at which the wood has been carbonised, and the following table by Violette shows how wide the limits may be:—

[1] Wagner *Jahresb.*, 1855, 457

Temperature of carbonising.	Yield of charcoal in percentage of wood used. Wood dried at 100°C.	Composition per 100 parts of charcoal.			
		Carbon.	Hydrogen.	Oxygen.	Ash.
280	36·2	71·6	4·7	22·1	0·57
350	29·7	76·7	4·1	18·4	0·6
432	18·9	81·6	1·9	15·2	1·2
1,030	18·7	81·9	2·3	14·1	1·6
1,160	18·4	83·3	1·7	13·8	1·2
1,250	17·4	88·1	1·4	9·2	1·2
1,300	17·5	90·8	1·6	6.5	1·1
1,500	17·3	94·5	0·7	3·8	0·7
above	15·0	96·5	0·6	0·9	1·9

Experience with Charcoal

Handkop[1] after using wood charcoal in place of gas coke for a considerable period in a small carbide plant found that 780 kilos of wood charcoal were needed to make 1,000 kilos of carbide, and that a mean output of 4·15 kilos of carbide per E.H.P. day could be obtained.

This is higher than the result he obtained with coke, and Handkop attributes this to the greater ease with which wood charcoal can be converted into graphite.

The drawbacks to the use of Charcoal

A great trouble with charcoal is that, when finely ground, the charcoal powder is so light that it is largely driven off from the mixture by the rush of gases generated in the actions going on in the arc, and far too large a proportion of it is carried away into the air as dust, destroying the homogeneous nature of the mixture and leaving an excess of lime.

Charcoal briquettes

This, however, can be obviated by mixing the ground-up charcoal into a paste with tar, pressing this into briquettes, and then burning out the hydrocarbons and granulating, or as is now often done, briquettes may be made at once of the right mixture of lime and charcoal powder, and when properly compressed and

[1] *Zeit. Angen. Chem.*, 1899, 25, 592.

carbonised at a fairly high temperature, it will leave the mixture in a very convenient form, the cost, however, of making the briquettes being a drawback to the process. This, on a large scale, is not as great as might be expected, and where charcoal is cheap, and the price of anthracite or good coke high, owing to the difficulty of carriage, such a process might be commercially successful.

Possibility of using Charcoal

In the same way attempts have been made to utilise the finely divided carbon which can be obtained from tar, and which consists of the residue left in the tar by the decomposition of hydrocarbon gases in contact with the hot walls of the gas retorts, part of the carbon being deposited in the form of a hard crust on the top of the retort, which is known as retort carbon, while the remaining portion separates as a fine powder, and is swept forward by the gas, and collects in the tar in the hydraulic main and condensers.

Tar Carbon

Another form of carbon the use of which has been advocated is peat charcoal, and also charcoal made from turf; but in spite of the large area of peat bogs existing in different parts of the world, the cost of getting it into a fit condition for carbide making renders it unlikely that it will ever be very largely adopted for the purpose of making carbide, and it is evident that no form of carbon, which is only obtainable as a bye-product, or in very limited quantities, could ever be used for this purpose save in very small installations, as the supply would soon become inadequate, and the price would rise to a prohibitive point, and it is this factor which prevents the use of retort carbon, which would be the ideal form to use.

Peat and Turf Charcoal

For these reasons it may be generally accepted that the carbon used for the manufacture of carbide will be practically restricted to anthracite and metal-

Possibilities of Bitumenous Coal

lurgical coke, whilst, if at some future time the idea of pre-heating the materials be more generally accepted than at present, some bituminous coals may be employed for this purpose, and the gases evolved used to pre-heat the material before its being exposed to the action of the electric arc.

The influence of the impurities in Carbide mixture on the purity of the Acetylene

The author has endeavoured to trace the influence of the impurities in the material used for carbide-making upon the percentage of phosphuretted and sulphuretted hydrogen present in the acetylene.

In order to do this, a number of analyses were made of the lime and coke used in making the carbide, and of the acetylene generated from it; but beyond the general result that pure materials yielded the purest gas, little information was obtained. The following table of some of the results will be of interest, as giving a general idea of what may be expected from materials in which the percentage of impurities is known :—

Analytical Results

Lime.		Carbon.		Acetylene.		
Percentage, P_2O_5.	Percentage, SO_3.	Percentage of Phosphorus.	Percentage of Sulphur.	Yield of Gas per kilo. of Carbide.	Percentage of PH_3.	Percentage of H_2S.
nil	0·46	trace	0·84	313 litres	0·071	0·166
0·28	0·21	trace	0·71	306 ,,	0·17	0·16
0·03	0·55	0·004	0·58	310 ,,	0·095	0·12
0·16	0·79	*nil*	0·33	285 ,,	0·026	0·085
nil	0·001	*nil*	0·06	320 ,,	0·004	0·041
0·18	0·15	0·005	0·09	305 ,,	0·14	0·10
nil	*nil*	trace	0·07	290 ,,	0·012	0·05
nil	0·02	0·016	0·77	309 ,,	0·049	0·043
0·048	0·128	trace	0·89	284 ,,	0·056	0·152

It is interesting to note that even with materials so pure that it has not been possible to quantitatively estimate the phosphorus present in the lime and carbon, that distinct traces of phosphuretted hydrogen

are found in the acetylene, probably due partly to concentration taking place when, roughly stated, two tons of material are converted into one of carbide, and partly to impurities in the electrodes used.

Conclusions to be arrived at

As the industry grows, and careful analyses of the materials and carbide are multiplied, it will probably become possible to formulate definite rules as to the limits of impurity allowable in the materials, but at present all that can be said is that the lime should not contain more than 0·05 per cent. of phosphorus pentoxide, and the coke or other form of carbon more than 0·01 per cent. of phosphorus.

Influence of the proportions of mixture on purity

The purity of the acetylene is also partly dependent on the proportions in which the materials are mixed in making the carbide, as excess of carbon has a great purifying effect by reducing the compounds containing the phosphorus and sulphur, and these elements are then volatilised during the formation of the carbide. For this reason it is more important to use pure lime and carbon in making "run" than "ingot" carbide, as with the former the lime is nearly always in excess to facilitate the fusion of the mass, and this tends to prevent volatilisation of the important impurities.

Proportions of Lime and Carbon required by theory

Having obtained the purest possible lime and carbon, the next point is to determine the right proportions in which to mix them, in order to obtain the best results in the electric furnace.

When lime and carbon interact, they do so according to the equation :—

Lime.		Carbon.		Calcium carbide.		Carbon monoxide.
CaO	+	$3C$	=	CaC_2	+	CO

and this formula requires that there should be 56 parts by weight of lime, with 36 parts by weight of carbon. In practice, however, the lime and carbon are never quite pure, and allowance has, of course, to be made for this.

Ratios adopted by various experimentalists

Moissan, in his paper on calcium carbide, takes 120 parts of lime and 70 of carbon, which is equal to 63·2 per cent. of lime and 36·8 per cent. of carbon; Willson, in his patent, gives 90 of lime to 60 of carbon as the most advantageous mixture, which works out at 60 per cent. of lime and 40 of carbon, whilst Bullier gives the theoretical proportion of 56 to 36, which is equivalent to 39·1 of carbon and 60·9 of lime.

Carlson's experiments with excess of Carbon

B. Carlson of the Deutschen Gold und Silber Scheide Anstalt, at Frankfort, made a number of experiments in order to see if excess of carbon in the mixture prevented the formation of crystalline carbide, and found that even if the theoretical proportion of carbon was more than doubled, the mixture could be fused and perfectly crystalline carbide obtained, if a sufficiently strong current were employed.

Proportions taken: lime	54	54	54
„ „ carbon	48	54	81
Condition of the carbide.	Crystalline.	Crystalline.	Crystalline.
Gas yielded by the carbide litres per kilo	293	293	250
Percentage of true carbide	84	84	71·8

Generally adopted proportions

The usual proportions now adopted in most ingot carbide factories are 100 of lime to 70 of carbon, whilst in order to obtain fusion at a slightly lower temperature, and the carbide in a more liquid state, most makers of run carbide use a rather higher proportion of lime, with the result that run carbide has often a lower gas-generating value than a good ingot carbide.

Influence on the yield of Gas

An excess of carbon in the mixture affects the yield of gas from the carbide far less than an excess of lime, the latter seeming to remain in solution in the carbide.

The coarseness of the mixture

The degree of fineness to which the carbide material should be ground has already been mentioned in considering the various forms of electric furnace, and as a generalisation it may be stated that fine grinding

has, up to the present, been the rule when ingot furnaces were to be employed, whilst a point of economy claimed for the furnaces making "run" carbide was that granulation, not grinding, was required.

Effect of fine grinding

The idea always has been that in the ingot process a good deal of the economy was derived from the arc being well buried in the mass of material so finely ground that the gas generated by the interaction in filtering between the small particles should part with most of its heat, whilst the intimacy of mixture, as well as fineness of grain, caused the interactions leading to the formation of carbide to take place directly the required temperature was reached, so that if the right current density to just raise the temperature to this point was being employed, no fear of overheating the carbide existed.

The disadvantages of fine grinding

The great drawbacks to fine grinding are that it is costly, that the rush of hot gases through the fine ground material naturally tends to the separation of two substances of such different specific gravities as carbon and lime, destroying the homogeneous nature of the mixture, whilst the finer particles driven out of the furnace by the rush of gases contaminate the air of the factory and render it unhealthy for the workpeople.

Fine grinding not necessary with some forms of furnace

Later experience with closed ingot furnaces of the Frankfort type seem to show that fine grinding is not the necessity supposed, and if, on extended working, this proves to be the case, it will be an enormous gain, as it practically solves the dust question.

Mills for fine grinding

Where fine grinding is necessary, by far the best form of mill is the continuous feed and discharge Ball mills, as they are the only ones that the coke grit does not seriously affect.

Coke must be dry for grinding

In grinding coke it is absolutely essential that it should be quite dry, otherwise it clogs both the mills and the screens, and also

mixes badly with the lime. Under no conditions should it contain more than 0·5 per cent. of moisture, so that it is advisable to use a special drying hearth, which, in a carbide factory with plenty of flue heat, should not prove an expensive item.

Granulating machinery

Where granulated material instead of ground is to be used, the granulating machinery made by Speyerer is found to work much better than the old mills or jaw crushers, and gives only a very small percentage of dust. In all large works labour-saving appliances are now finding a place, and automatic weighing and mixing machines feeding into elevators are now being introduced into most carbide works.

Power for Carbide works

In establishing a carbide works, the price at which power can be obtained is naturally the governing factor, and water power at present seems to be the only form which offers a sufficiently low-priced production of electricity to make acetylene a commercial success. In round figures an electrical horse power per year will yield a ton of carbide, and three years ago water power was looked upon as somewhat scarce in Western Europe; but the demand has caused the discovery of a supply, and water power is being freely offered at prices that range from 12*s.* to £4 per E.H.P. per year. Most of these, however, prove to be of a very unsatisfactory character, being either too small to be worth working or else a raging torrent in winter and dry in summer. It may be taken that satisfactory water power in Europe costs £2 to £2 10*s.* per E.H.P. per year, and the value that it is to the manufacturer varies with the facilities of carriage and the possibility of getting pure lime and carbon at a reasonable rate.

Water power

Steam power costly, but many advantages

Steam power has the great advantage that it can be generated close to the lime and carbon supply, but, save under exceptional circumstances, cannot enter into competition with water power, as the

lowest price at which it can be obtained on a large scale is £5 to £6 per E.H.P. per year, whilst, as a rule, it is much higher.

Possibility of Carbide making, yielding a level load in Electric light stations

When the demand for carbide first arose it was hoped that its manufacture would prove the means of providing a level load for the big electric light stations, and that instead of standing with banked fires for a considerable proportion of the 24 hours, they would run continuously and utilise the extra current for carbide making to the mutual advantage of both sources of light. The idea, however, does not seem to have been acceptable to them, and carbide is still only made at the special carbide works.

The Gas Engine a promising source of power

At the present time it looks as if the supply of carbide would in a short time catch up with the demand; but if this should prove not to be the case, and if the available water power should be insufficient, the most promising direction in which to look for cheap power is the gas engine, which shows indications of playing an important part in the future as a source of energy.

Cost of power from gaseous fuel

Rapid strides are being made in perfecting the gas engine, and experiments are showing that with water gas made by such improved processes as that devised by Dellwik, or even with generator, blast furnace, or Dowson gas, power can be obtained at about £3 to £4 per E.H.P. per year, and the time may be not far distant when the advantages of being able to erect the plant near to the pit and quarry providing the materials, may make gas power a serious rival to water power, more especially as rents and repairs, which build up the cost of water power, are going on all the year round; whilst the fuel, which forms the chief item in other forms of power, is only used when the power is required.

The conversion of power

When chemical or other work has to be done on a large scale by means of electricity, the current re-

into electrical energy

quired must be generated by means of a dynamo, an arrangement by which mechanical power obtained from a steam engine, gas engine, or more economically by means of turbines using water power, can be converted into electrical energy. To avoid the cost of the fuel required for a steam engine, there has been a tendency of late years to transfer the large electrochemical industries to the neighbourhood of some natural supply of water power. It is, however, often necessary to convey the electric current for considerable distances from the power stations where it is generated to the actual locality where it is used, and it may be convenient to consider briefly what are the conditions which may determine in any given case the choice of the particular type of dynamo to be used. The available power in any flow of electricity depends upon the current strength and the electromotive force. The product of the current in ampères and the E.M.F. in volts divided by 746 will give the equivalent indicated horse-power, subject to a correcting factor in the case of alternating currents, to be alluded to later. It would be very uneconomical to transmit this power in the form of large ampèrage and small voltage. Wherever a current flows there is a waste of power in heating the conductors which is proportional to the square of the current strength and to the resistance of the conductors. Consider the case of a certain amount of power to be conveyed either at 100 ampères and 100 volts, or at 10 ampères and 1,000 volts: since the current in the former case is ten times as much as in the second, the waste in heat will be 100 times as great if the same leads are used, or if the same loss is accepted in each system, the leads in the second case may be only one-hundredth of the cross section of the former, and the prime cost of the installation will be enormously reduced. Of course, at the higher voltage it will be necessary to have better

Transmission of electrical energy

Waste of power in transmission

Necessity of high voltages

insulation on the leads, which will reduce to some extent the advantage gained in first cost, but will still leave a very large margin in favour of the higher pressure. It follows, then, that if power is to be conveyed for any distances exceeding a few hundred yards, it is essential that high voltages should be employed. But in the actual chemical work to which the electrical energy is applied, it is great current strength at comparatively low voltage that is wanted. In the formation of calcium carbide in the electrical furnace, currents of perhaps 1,000 or 2,000 ampères are used at a voltage not exceeding 70 or 80. The high-pressure current must be transformed at the place where it is utilised into one of low pressure and corresponding great current strength. It must be remembered also that the current will be generally required to do some motor work; the processes of grinding, mixing, elevating, and transporting the materials, etc., can be very conveniently and economically carried out by machines driven by electricity, and the electric light in either the glow or arc system would generally be employed in the workshops.

for transmission to a distance

Low voltage and great current strength required for the electrical furnace

We have to consider, then, how the different types of dynamos and the currents produced by them lend themselves to these purposes. The currents employed may be either direct (or continuous), like those obtained from voltaic cells, in which the flow is always in one direction, and at approximately the same strength under the same conditions; or, on the other hand, they may alternate in direction many times in a second, and at each alternation rise gradually from a zero value to the maximum strength, and fall again to nothing. In a purely electro-chemical industry, like electro-plating, such currents would be useless; the metal deposited when the current flowed in one direction would be taken off again at the next

Direct and alternating currents

reversal. Where, however, it is the heat produced by a current that is concerned, either system will give the same result, since the amount of heat developed is obviously independent of the direction of flow. An alternating current will give the same light in a glow lamp as a direct current of the same strength. The heat developed in an arc lamp will also be the same in either system; but there is the difference to be noticed, that while in the direct current the carbon attached to the positive pole will be much hotter than that connected to the negative, in the alternating current, since each in turn is positive and negative, obviously the temperature of both is the same. In the direct system the temperature of the crater of the positive carbon is usually assumed to be about 3,900° C.; that of the negative will be much lower, perhaps not exceeding 2,800° C. Since the light emitted is proportional to a high power of the temperature, more than eight times as much light is given out by the positive as by the negative. The light of a direct current arc is generally assumed to be about twice as much as that of an alternating for the same power absorbed, since in the latter each carbon has a temperature intermediate between those of the carbons of the former; the total heat developed in each case will, however, be the same.

The more equal distribution of heat with alternating currents

Considerations governing the choice of type of dynamo to be employed

The choice of the type of dynamo to be used in an industry such as the production of calcium carbide will be affected by the considerations mentioned, viz. their adaptability to the production of electrical energy at high pressure and subsequent conversion to low pressure, the ease and facility with which motors can be worked, and the temperature limits which may be found most effective in the reduction of the material. The consideration of the first cost and upkeep of the machine and liability to be injured by the large and sudden fluctuations in the load,

which are unavoidable, must also obviously be taken into account.

Early forms of dynamo

The dynamo first invented was of the alternating type; no arrangement was used to commutate or rectify the current generated so that it might flow always in the same direction in the outside circuit. The alternator is consequently a simpler piece of mechanism than the direct current machine which involves the commutating device, since it follows from an elementary consideration of first principles that the current must alternate in direction in the parts of the machine in which it is generated. In every form of dynamo the current is due to the number of lines of magnetic force enclosed by a conductor. This conductor generally takes the form of a coil of wire of more or less turns called the armature, which revolves in a powerful magnetic field. The E.M.F. generated depends upon the change per second in the number of enclosed lines multiplied by the number of turns of wire round the coil.

The magnetic field

The magnetic field in which the armature rotates was originally due to a battery of permanent steel magnets, but is now formed by powerful electromagnets magnetised by a current of electricity usually derived from a small auxiliary dynamo of the direct current type. An E.M.F. is set up in one direction in any given coil as the number of enclosed lines of force is increased; in the opposite direction, as it is diminished. From this it follows that since the same coil cannot indefinitely gain nor lose lines, the direction of the E.M.F. must be reversed at least twice in every revolution.

Modern alternating current dynamos

In alternating current machines in present practice, this change of direction occurs between the limits of 40 and 300 times in a second. The two ends of the conductor forming the armature are usually connected to the insulated rings which are fastened to the armature and revolve with it.

The current is collected by fixed brushes which press against these rings and convey it to the outside circuit. The mechanical construction is simple and strong; very little trouble is experienced by any sparking between the brushes and the rings, even when a high voltage is employed. In a direct current machine the successive coils of wire wound on the iron core of the armature are connected to corresponding commutator segments insulated from each other and from the shaft to which they are attached and with which they revolve. Brushes fixed in position serve to collect from the outside circuit a current which is invariable in direction and does not perceptibly fluctuate in amount during a revolution of the armature. It is, however, difficult to suppress all sparking as the commutator segments pass the brushes, and this sparking and the difficulty of satisfactorily insulating the adjacent segments places a limit upon the E.M.F. which can be generated by this class of machine. About 500 volts may be assumed as the limit in ordinary practice obtained from continuous current dynamos.

Direct current dynamos

Troubles limiting the E.M.F. generated

E.M.F. of self-induction, and its effects on an alternating current

Whenever a current of electricity varies in strength, *i.e.*, increases or diminishes, an E.M.F., called the E.M.F. of self-induction, is set up opposing the change, giving rise to effects very similar to those associated with the inertia of ordinary matter. In the outside circuit of a direct current machine, these effects can only be apparent when the circuit is made or broken, or to a less extent when the strength is altered. They are chiefly manifested by the heavy sparking which occurs when the switch of a circuit containing much self-induction is thrown over. An alternating current may be figured as a wave motion always rising and falling in strength and reversed in direction perhaps 160 times in a second, so that the whole cycle is gone through in one-eightieth of a

second. It is only at the crest and trough of these waves that the current momentarily remains at a constant strength. Since the E.M.F. of self-induction depends upon the rate at which the current is changing, it will be greatest when the current is reversed in direction, at which instant its actual value is nothing, and there will be no E.M.F. due to this cause when the current has its greatest values, viz., at the wave crests and troughs. If we figure the whole wave motion as completed in a cycle of 360°, the E.M.F. of self-induction is 90° behind the current, and always opposes the change of current strength. It is owing to this effect that the properties associated with an alternating current differ so much from those which have been studied for many years in connection with voltaic cells. In a direct current circuit the current is always acting in "phase" with the E.M.F.; in the alternating circuit the current is proportional at any instant to the resultant of the E.M.F. impressed upon it from the generator, or other source, and of the E.M.F. of self-induction. The current consequently "lags" behind the impressed E.M.F. by an angle which depends upon the self-induction, or rather upon the proportion which the latter bears to the resistance of the circuit. If the circuit contains coils of wire of several turns, more especially if they are wrapped round iron cores, the effects of resistance may be almost negligible compared to those of self-induction. In this case the lag of the current may amount to nearly 90°, and the peculiar condition arises that although the current and E.M.F. may both be great, no power would be developed; such a current would be spoken of as "wattless."

The "lag" of the current

In all cases the power developed is the product of the E.M.F. and current multiplied by the cosine of the angle of lag. In a direct current there is no lag, and since the cosine of 0° is 1, the factor disappears. If

The power developed

the lag is 90°, since the cosine of 90° is 0, the power also vanishes. In ordinary alternating conditions the factor varies between 1 and 8, so that for the transmission of a given amount of power for heating or other purposes, more current must be transmitted along the leads and more current generated in the machine in the alternating than in the direct system.

More current needed with alternating than with direct system

On the other hand, the great advantage of the alternating system lies in the fact that by means of a "transformer"—practically an iron core wound with two sets of insulated wire—it is possible to convert electrical energy received in the form of small current strength and high voltage into the opposite conditions, viz., large currents and small voltage. The transformer is practically based on the same general principle as the Ruhmkorff induction coil used for many years past in laboratories to obtain a very high E.M.F. by means of a few voltaic cells. In each apparatus an iron core is wound with two sets of insulated wire, the one of many, the other of few turns. The "primary" is connected to the source of E.M.F., and is traversed by a current which in the induction coil is rapidly started and stopped. In the transformer the rapid periodic reversal of the current serves the same purpose. An E.M.F. is set up in the "secondary" wire wound on the same core, which bears approximately the same ratio to the primary E.M.F. as the number of turns in the secondary does to the number of turns in the primary. As the E.M.F. is decreased, the current is increased nearly in the same ratio, and *vice versâ.* In the case of carbide works situate at some distance from a waterfall, the current may be generated at the power station at say 1,000 ampères and 100 volts transformed immediately into 10 ampères and 10,000 volts, transmitted along the leads with very little loss and by a small conductor, and transformed at the electrical furnace into 1,000

Transformers and the principle of their construction

ampères and 100 volts. All these transformations involve some loss, but the efficiency of a transformer is generally over 90 per cent., and the apparatus itself, having no moving parts, requires no attention, is not costly in the first outlay, and is not liable to get out of order.

Loss involved in transformation of the current

The substitute of a transformer in the direct system is a rotary "converter" or "motor generator." Two armatures revolve upon the same shaft and between the same field magnets. The one armature receives the high-pressure current, works as a motor, and sets both armatures in rotation. The other armature acts as a generator, and gives out electrical power at a lower voltage. In this case the number of turns of wire on the second armature is less than that on the motor armature in the proportion in which it is required to reduce the electrical pressure. Obviously the same arrangement may be used for the converse conditions, to raise instead of to lower the pressure It is not necessary that there shall be two separate armatures; two windings on the same core connected respectively to the primary and secondary circuits are sufficient, but there must be two commutators, and the mechanism, though comparatively simple, requires more attention and is more liable to derangement than the stationary transformer, which has the great advantage of no moving parts. Nor, again, can the very high pressures, reaching in some recent alternating installations as high as 29,000 volts, be used in this case. The rotary converter can also be used if required to transform alternating currents into direct, or *vice versâ*.

Converters or motor generators

Principle of the converter

Alternating machines of the type considered so far, giving what are called "single phase" currents, do not lend themselves so conveniently to motor purposes as the continuous type. The motor which is driven by an alternating current must generally be brought

Single phase currents for motor driving

up to the right speed by hand or some auxiliary mechanism before it is connected to the circuit, and the field magnets are usually excited from a continuous current derived from some other source involving additional outlay and further complications.

Polyphase machines and their advantages

During the last few years, however, alternating machines have been largely constructed to embody the advantages of the easy conversion of power from high to low pressures, and *vice versâ*, peculiar to the alternating current with the facility for driving motors associated with the direct current. These machines give rise to what is called "two phase" or "three phase" currents. In the two phase machines we may consider the armature as wound with two independent sets of coils, each set connected as usual to collecting rings and fixed brushes, and separate leads which convey the current to the receiving station. The winding of the armature coils is always such that the one current is always 90° ahead of the other. In other words, when the one current is at a maximum the other is at a minimum value. The four leads required in this system may be reduced to three, each current as it were using a common return wire.

The principle of the polyphase motor

To utilise these currents for motor purposes, an iron ring may be imagined wound with copper wire, so that one-half of its surface is traversed by currents brought by one set of leads; the other half, at right angles to the first, is traversed by currents conveyed by the other set. Remembering that these currents must be regarded as 90° apart, the one having its greatest effect where the other vanishes, the result is to set up a pair of magnetic poles which revolve in the iron ring with the same frequency as the alternating currents which give rise to them. If the period of the latter is one-hundredth of a second, a magnet pivoted in the interior of the ring would revolve 100 times in a second by the mutual attrac-

tion between its poles and the revolving poles of the ring. A pivoted magnet is not, however, necessary; a disc plate or cylinder of copper or other conducting material will have eddy currents set up in it by the passage through it of lines of force due to the moving poles. The reaction of these induced currents will give rise to a force causing rotation of the conductor on the same principle as in the old experiment of causing a copper plate to follow the movement of a whirling magnet, the Arago disc experiment. In this system there is no "dead point," and the motor bears somewhat the same analogy to the single phaser as an engine with two cranks at right angles does to a single crank engine. It is, in consequence, self-starting, and has the great advantage over the direct current motor of requiring no commutator. The moving parts are of the most extreme simplicity, and there is absolutely no connection necessary between the revolving armature—if so it should be called—and any outside circuit.

Advantages of the polyphase machine

The above brief description is intended only to explain the general idea, and not the practical details of the mechanism used, which, moreover, varies much in different cases.

Triphase circuits

In a three-phase generator three independent currents are collected from three sets of coils symmetrically placed round the armature core, follow each other with a phase difference of 60°, and are connected to three leads; in this case each lead may be regarded as acting in turn as the return lead for the other two. One end of all three armature coils may be connected to a common junction. The iron ring which acts as the field magnet of the motor may be wound symmetrically with three sets of coils receiving these currents, and the motor bears an analogy to a three-cylinder engine with cranks 120° apart.

The polyphase system has also the advantage that

Compensation possible with polyphase systems

if two or three sets of carbons are used in the same furnace, as is done by Memmo, the unavoidable fluctuations of current which must arise from the changes in the arc length, and the resistance of the incandescent matter between the carbons, will not throw such heavy strains on the generating mechanism. The rapid changes are not likely to occur simultaneously in the three arcs, and there will consequently be a tendency to mutual compensation.

Cost of the various types of generators

The efficiency, weight per E.H.P., and cost of the machines of the types considered—viz., direct current, single phase, two and three phase—do not differ very largely when machines of the same output are considered, and the choice must depend upon the local conditions of each installation. Upon the whole, the polyphase system seems to offer the greatest number of advantages, and will probably be that most largely adopted in the future.

Continuous and alternating currents

The first question to consider is what kind of current is best for the purpose—continuous or alternating. Alternating-current furnaces are largely in use in the United States, and appear to have some very substantial advantages, as follows:—

Advantages of the alternating current

1. The dynamo can be made of more mechanical construction, much more suitable to stand the sudden fluctuations of load which are liable to occur in a carbide plant.

2. Sparking at the commutators, which gives considerable trouble in some machines, is, of course, entirely obviated.

3. By a suitable arrangement of transformers, the variation of load on the furnaces may be brought to a minimum.

4. The cost of attendance on, and upkeep of, the dynamos is very much less than when direct-current machines are used.

There is one apparent disadvantage: Since very

heavy masses of copper and iron must be used on furnaces carrying heavy currents, there might be some loss and heating trouble due to eddy currents. This, however, could be obviated by careful design.

Relative efficiency of direct and alternating currents

With regard to the relative efficiency of direct and alternating current, there appears very little to choose between either as regards quality and output per H.P. day, though the Americans claim a somewhat larger output for alternating current.

The current governed by the work to be done

Using a continuous current, there is no phase displacement caused by self-induction. The phase displacement with alternating currents using big currents in carbide manufacture becomes a considerable one if special precautions are not taken. Continuous-current dynamos are affected more than alternating-current machines by fluctuations of the current; and the sparking, and therefore destruction of commutators, being greater, it is better to use alternating currents. When the current is switched on, this causes, with continuous-current machines, difficulties which do not occur with alternating machines. In big factories it is a matter of indifference which kind of alternating current is used, but this is not the case in small works. Two-phase current is suitable for factories of 600 to 1,800 H.P., triphase current for factories of 400 to 1,200 H.P. If the two-phase dynamos are fitted with a zero potential cable, such machines may be used with advantage for 400 to 800 H.P., but not for 800 to 1,800 H.P., because the investment necessary will in these cases be higher than with other currents.

Current tension

If the carbide furnaces are situated not further than 75 to 100 metres from the dynamos, it is best to construct them for currents at low tension, that they may be directly connected with the furnaces. If the furnaces are further away, the generator must be constructed for high tension, and the current must be transformed to the required voltage. The phase dis-

Trans-former

placement being important in carbide works, it is best to use dynamos with a low periodic number—for instance, twenty to twenty-five per second. If a works possess several dynamos, they must be coupled in parallel, whilst the cables should be so arranged that the induction shall be as small as possible. With each furnace is connected a switchboard containing ammeter, voltmeter, and a simple switch for each pole.

Arrangement of furnaces and conductors

In larger works five to eight furnaces may be coupled together and connected with one big conductor, and the conductors of several groups in large works may be switched on in series, so that the dynamos may be built for higher tension and lower current. Using polyphase currents in carbide works where several furnaces work with the same phase, polyphase transformers need not be used, but better single-phase transformers, so as to divide the polyphase current into several single-phase currents, by which arrangement the cables employed for the secondary current may be much smaller.

Up to the present time copper only has been used for the conductors, but at some works is being now replaced by strips and flexible cables of aluminium.

Electrical energy needed in making Carbide

The figures which have been given as to the electrical energy needed in the making of calcic carbide vary from three kilos per kilowatt day to twelve kilos for the same amount of energy, these absurd discrepancies being due to these calculations being made either by electricians devoid of any chemical knowledge, or by chemists equally ignorant of electrical data. In making any calculation which shall be of practical value, one must clearly bear in mind that there are several factors which seriously affect the results, as calculated from the beautiful thermo-chemical data given us by Thomsen, Berthelot and others.

These are :—

1. The lime and carbon used are neither of them

pure, and the foreign matters present have to be heated to the same temperature as the carbide.

Factors to be considered in calculating the energy required

2. The materials are rarely, if ever, used in the exact theoretical proportions.

3. There is a considerable loss of heat from the furnace, due to radiation, conduction, and the escape of heated dust and gases, and the heat withdrawn with the carbide, and by the poles, and walls of the furnace.

4. The carbide made is not pure carbide; with run carbide it is a fairly homogeneous mixture of true carbide, lime, and other impurities, whilst with ingot carbide there is the kernel of nearly pure carbide, and the crust which contains less and less true carbide the further it is away from the arc.

It is manifestly impossible to arrive at any exact estimation of such varying factors as these, but by taking the amount of energy required, as arrived at by theoretical data, and then comparing the result with those obtained in practice, and averaged over a considerable period and checked by careful chemical analysis, we are enabled to form a fairly just estimate of what the losses are, and how far practical results fall short of the theoretical yield.

The theoretical amount of energy required to form carbide from lime and carbon has already been mentioned (see p. 260) in considering Landin's calculation of the saving to be obtained by preheating the carbide material.

Bredel's calculation of the amount of energy required

The first calculation of the kind was published by Bredel in the *American Gaslight Journal*, February 25th, 1895, in which he works out the calories necessary to bring about the reaction of 87·5 parts by weight of lime with 56·25 parts of carbon, with formation of 100 parts of calcic carbide and 43·75 of carbon monoxide in the following way:—

1. Heat absorbed in raising two-thirds of the carbon —37·5 grams—to the temperature of formation of

carbide, 3,000° C., on the assumption that the specific heat of the carbon is 0·46—

$$37{\cdot}5 \times 3{,}000 \times 0{\cdot}46 = 51{\cdot}75 \text{ calories.}$$

2. The heat necessary to decompose 87·5 grams of lime into 62·5 of calcium and 25 of oxygen = 206·25 calories.

3. The heat necessary to bring about the combination of the calcium and carbon, which is so small that it is omitted from the calculation.

From these factors has to be deducted the heat generated by the combination of 18·75 grams of carbon to form 43·75 grams of carbon monoxide, equal to 44·68 calories. Then

$$51{\cdot}75 + 206{\cdot}25 - 44{\cdot}68 = 213{\cdot}32 \text{ calories}$$

required to form 100 grams of calcic carbide, or 2,133·2 per kilo.

Pictet's estimate of the amount of electrical energy used

Pictet, in his pamphlet *Le Carbite*, published in 1896, p. 28, gives 182·5 calories as the amount of energy required to produce 64 grams of calcium carbide, of which 102·6 were needed by the reaction, whilst the remainder was required to give the necessary temperature to the material used.

Sieber's calculation

Sieber[1] also calculated the heat necessary for the formation of carbide, and leaving out of consideration the energy necessary to raise the raw materials to the temperature of the furnace, came to the conclusion that 9·38 kilos of carbide can be made per E.H.P. per twenty-four hours.

Such calculations are of no practical value, as they leave out of consideration some of the most important factors in the absorption of energy; and if one desires to come to any useful conclusion as to the amount of energy required, the practical working proportions of material must be dealt with, and the percentage of true carbide in the product formed, determined.

[1] *Chem. Zeit.*, 1898, 31, 308.

Taking ordinary carbide practice, 100 parts by weight of lime and 70 of carbon yield 100 of calcium carbide of approximately 80 per cent. purity, and the factors which would enter into a calculation made on a practical basis are :—

Calculation of the energy required in Carbide making based on practical working

1. Energy needed to raise 100 grams lime and 70 grams carbon to 3,000° C.

2. Energy needed for the reaction that forms 80 grams of carbide and 35 of carbon monoxide.

1. The specific heat of lime equals 0·2 and of carbon 0·45, hence the calories necessary to raise the temperature to 3,000° C. will be

Energy necessary to raise the materials to the melting point of Carbide

$$\left(3{,}000 \times 0{\cdot}2 \times \frac{100}{1{,}000}\right) \times \left(3{,}000 \times 0{\cdot}45 \times \frac{70}{1{,}000}\right) = \begin{array}{c}154{\cdot}5\\ \text{calories.}\end{array}$$

2. 100 grams of impure lime are taken, but 70 of calcium oxide only interact to form 80 of true carbide, and in the same way only 45 of the 70 grams of carbon enter into the action.

The data we have are :

Energy needed in the formation of Carbide from Lime and Carbon

Heat of dissociation of the gram molecule of calcium oxide = 132· cal.[1]

Heat of formation of the gram molecule of calcium carbide = 0·65 cal.

Heat of formation of the gram molecule of carbon monoxide = 28·8 cal.

So that the calories necessary to form 64 grams of pure carbide are—

$$132{\cdot}65 - 28{\cdot}8 = 103{\cdot}85 \text{ calories,}$$

and the 80 grams formed will require 129·8. On now adding together 1 and 2 we obtain

$$\left.\begin{array}{l}\text{For heating, } 154{\cdot}5 \text{ calories}\\ \text{For reaction, } 129{\cdot}8 \text{ calories}\end{array}\right\} = 284{\cdot}3 \text{ calories,}$$

or for the kilogram of pure carbide, 3,553·75 calories.

Carbide made per E.H.P. day

For all practical purposes the ratio between calories and electrical horse power may be taken as 1 E.H.P.

[1] Determined by de Forcraud. *Compt. Rend.*, 120, 682.

to 550 calories per hour, so that 1 E.H.P. would give the 3553·75 calories, and make 1 kilo of pure carbide in 6·4 hours, or 3·7 kilos, equal to 8·1 lbs., per E.H.P. day of 24 hours.

This figure is in close agreement with the best results obtained in practice. At Foyers, for instance, the daily yield calculated to pure carbide is 3·78 kilos per E.H.P. per day.

In this calculation it must be noted that the whole of the heat generated is lost, and this is practically true in the ordinary working of the furnace.

Rough statement as to power needed

For all practical purposes it may be stated that 1 E.H.P. per year will yield one ton of carbide, so that the available H.P. of a works will represent its annual output in tons when worked to its full capacity.

Tapping v. ingot furnaces

The question of the type of furnace to be employed has been already fairly fully discussed in considering the various forms of running and ingot furnaces, but it may be added that the advantages of the running or tapping systems are smaller capital expenditure, slight economy in wages and material, and absence of crust in carbide, whilst against this must be placed the greater purity and higher output of ingot carbide for equal expenditure of electrical energy. The difference in output per E.H.P. day may be approximately stated as—

	Run carbide. lbs. per e.h.p. day.	Run carbide. kilos per kilowatt day.	Ingot carbide. lbs. per e.h.p. day.	Ingot carbide. kilos per kilowatt day.
Gross output per day	7·0	4·1	9·6	5·6
Net output—packed	6·8	4·0	8·0	4·77

The 9·6 lbs. per E.H.P. day including some crust, the elimination of which, and loss in crushing, gives the difference between gross and net output, whilst with run carbide it is only the loss in breaking which is allowed for.

The size of furnace

The size of the furnace used is of course governed by the type; if a running furnace is employed, the size

of the electrodes obtainable seems to be the only limit, whilst if an ingot furnace is adopted, experience shows that the best size is about 200 E.H.P., as a loss of efficiency is found if of smaller capacity, and larger furnaces give more trouble from consumption of the electrodes, and general wear and tear.

Current density

The best current density for such a furnace is about 12 to 15 ampères per square inch of electrode section, and a voltage of 55 to 65.

Injurious effects of overheating the Carbide

In making carbide, no matter what the form of furnace used, attention must be paid to preventing overheating or burning of the carbide when once it is formed. M. Nicolai has pointed out that overheating leads to dissociation of some of the carbide, and the result of this is well shown by remelting a sample of carbide of known composition, after which it develops about 12 per cent. less gas than before, whilst a second remelting more than doubles the loss. A second grave disadvantage of overheating also is that metallic calcium is produced, which, during the decomposition of the carbide by water, gives rise to hydrogen.

"Burnt" Carbide

In an extremely interesting paper by Gin and Leleux, they study the actions taking place in the electric arc as follows:

The actions taking place in the Electric Arc

"The conditions of adiabatic heating are impossible of realisation, but may be approached by striking the arc in the centre of an extremely poor conductor of heat, for instance, in the pulverised mixture which is used in the manufacture of calcium carbide. In such a centre, unmoved by the affinity of the electrodes, the arc excavates a small pocket presenting a small crater near the upper pole, by which the carbon monoxide and the vapours of lime, calcium, and carbon escape. The size of this cavity increases up to a certain limit, until a condition of equilibrium is reached, as when the volatilisation and chemical actions have ceased

The cavity of the Arc

the quantity of heat given off by the arc is balanced by the emissions towards surrounding centres.

After cooling it is observed that the walls of the cavity are stratified in concentric layers working from the interior to the exterior.

Structure of the walls of the Arc cavity

1st. A layer of brilliant graphite of blistered and frothy appearance.

2nd. A layer of crystallised calcium carbide.

3rd. The original and unaltered material.

From this it may be deduced that the interior temperature has been high enough for the tension of dissociation of the vapours of calcium and carbon to oppose the combination of the two bodies, which can only happen beyond the surface of the level, limiting the region of temperatures inferior to those of dissociation.

Theories which might explain the presence of the Graphite

If one does not wish to admit the dissociation of the calcium carbide, the presence of the graphite layer may be explained by the fact that the great temperature of the circuit would provoke so rapid a volatilisation of the lime that part would escape reduction, and the subsequent carburation leave an excess of carbon as residue. To us it seems probable that both these phenomena occur simultaneously.

Tension of the Arc

The tension of the arc varies with the state of the atmosphere. In the mixture used for calcium carbide, the stationary temperature being reached, we have obtained arcs at a tension of from 18 to 20 volts for a distance of 10 cm. $s = 100$ cq. $\frac{1}{s} = 10$. Under the same conditions, in the centre of a mixture of charcoal and oxide of manganese abundant vapours of metallic manganese are produced, and the tension may descend as low as 10 volts, the cavity formed being noticeably larger. The last observation accords with the increase of t with $\frac{p}{c}$.

Action of the Arc on Calcium Carbide placed in the cavity

If one repeats the experiment, and if, the stationary heat being reached, one introduces into the crater out of which the gases come some granulated calcium carbide, it shrinks rapidly, and even disappears altogether if the density of the current be sufficiently great. The vapour given off does not yield acetylene, from which it would seem that the carbide has been dissociated and not merely vaporised.

Proof of the dissociation of Calcium Carbide in the Arc

There is found in the cavity a deposit of coke, the skeleton of the compound which has ceased to exist. If the hypothesis of the dissociation of the carbide be rejected, it must be admitted that the graphite deposit existed before, and that the carbide simply filtered off after fusion through the porous layer of carbon. But if dissociation occurred, it would seem that the temperature at which it is produced is inferior to that of the volatilisation of the carbon, and that the calcium carbide cannot be vaporised in the state under which the experiments were made."

Carbide dissociates before the temperature of volatilisation is reached

In a further note on the dissociation of the carbides of barium and manganese, they show that these bodies cannot be volatilised without dissociation at the temperature of the arc, and also that the temperature at which they dissociate is lower than the volatilising point of carbon.

The Carbon Electrodes for the furnaces

The electrodes used in the electric furnace are an important factor of expense in carbide manufacture.

The best carbons, such as are made by Rudolph, Conradti or Lessing, are expensive, and the loss during the making of a ton of carbide amounts to from 10 to 16 shillings, according to the furnace used.

Some carbons are made so dense and hard that they will scratch glass, but these are mostly used for electrolytic work, and are not so good for carbide making.

The manufacture of Electrodes

In making carbons for carbide furnaces, pure coke and very slightly bituminous coal, such as anthracite or steam coal, are ground together, and having been

compressed under hydraulic pressure into a very dense mass, sometimes with a trace of tar, they are fired in a special furnace, and all volatile matter having been driven off, and the carbon from any hydrocarbons present deposited in a graphitic condition, they become good conductors of electricity.

The pressure required is high, but if too excessive the final firing causes the mass to bulge out of shape or warp, and considerable skill is required to obtain them of just the right density.

Properties of Calcium Carbide

Commercial calcium carbide varies very much in appearance, being sometimes in a fine crystalline condition, with its surface shot with iridescent colours, whilst other samples present a steel-coloured fracture, which on examination is found to consist of very minute crystalline faces. This difference of appearance was at one time thought to indicate differences in purity, but it is now generally recognised that they may be of equal purity, ingot carbide which has only cooled very slowly having formed large fine crystals which owe their wonderful colours to excessively fine films of oxide on their surface, whilst the steel-coloured variety is generally run carbide, the rapid cooling of which has only allowed the formation of very minute crystals.

Differences in the crystalline condition of Carbide

A very dark graphitic-looking carbide with streaks of blacker shade is often a bad carbide, and owes its colour to overheating in the furnace, which has caused dissociation of some of the carbide and deposition of amorphous carbon, the calcium having volatilised or being present in metallic form.

Importance of proper ventilation in Carbide works

In carbide works the greatest attention must be paid to thorough ventilation, and of course to absolutely tight roofs, as moisture is the chief enemy the carbide manufacturer has to dread, not only from its effect on the carbide, but on the raw material. In carrying out the ventilation, however, draughts at

the furnace level must be carefully avoided, as the carbons above the furnace are often unduly heated, and any draught causes them to burn away and waste, the same remark applying to the carbonaceous material in the mixture where open furnaces are used.

Carbon Monoxide

It has before been shown that as the interactions leading to the formation of carbide proceed, carbon monoxide is formed by the combination of the oxygen of the lime with one-third of the carbon used in the mixture.

Poisonous action of Carbon Monoxide

In the manufacture of 1 ton of carbide 1,232 cubic feet of this gas are produced, and as the smallest trace of it free in the air produces intense headache, whilst less than 1 per cent. inhaled for a short time may prove fatal, it is manifest that every precaution must be taken to prevent any escape into the air of the factory.

Effect of Carbon Monoxide on the blood

The poisonous properties of carbon monoxide are due to its forming a definite compound with the hæmoglobin in the blood. Under ordinary circumstances of respiration the blood corpuscles, which are chiefly composed of hæmoglobin, take oxygen from the air through the cell walls of the lungs and form a weak compound called oxyhæmoglobin, and during the circulation of the blood carry it to the various parts of the body where it is needed for burning up the waste tissues. When, however, the air contains any carbon monoxide, this gas combines with the hæmoglobin, forming a much stronger compound than the oxyhæmoglobin, with the result that the blood is robbed of its chief function, and death rapidly ensues. When, however, the gas has only been inhaled in very small traces, headache, and finally vertigo and insensibility occur. Under these conditions a workman who has been overcome can generally be quickly brought round again by inducing artificial respiration in the same way as would be

Treatment for Carbon Monoxide poisoning

Use of compressed Oxygen in cases of gasing

done in a case of drowning, or better still by taking a small bottle of compressed oxygen, the nozzle of which is fitted with an india-rubber tube. If this india-rubber tube be now placed in one nostril of the insensible man, and the other be closed and the mouth held shut, the oxygen can be turned on until the lungs are full, which will be shown by the puffing of the cheeks. The oxygen is then turned off, and by gentle pressure on the chest the gas from the lungs is discharged through the mouth, the lungs being then filled again in the same way as before. On repeating this two or three times the carbon monoxide compound in the blood is slowly decomposed, and the blood resumes its normal functions, whilst the man rapidly recovers.

In all works where carbon monoxide is generated in manufacturing processes, a bottle of compressed oxygen should be kept handy for this purpose.

Other gases formed from foreign matter present in the furnace

When the ingredients of the mixture are perfectly dry, and consist of pure lime and good metallurgical coke, carbon monoxide is practically the only gas formed by the action of the arc, but when anthracite or coke made at a low temperature is employed, the decomposition of the small quantity of hydrocarbons present lead to the formation of hydrogen, whilst if the coke or lime contain moisture, this not only abstracts heat from the region of interaction by its conversion into steam and dissociation, but also causes formation of a larger volume of carbon monoxide, whilst the hydrogen of the water vapour again adds to the volume of escaping gases. Every precaution must be taken to prevent access of air to the neighbourhood of the active zone, as it would not only produce excessive waste of carbon from the mixture and electrodes, but would also lead to the formation of cyanogen and nitrogen oxides.

Importance of keeping air from the heat zone of the furnace

The poisonous properties of the gases produced are not the only drawback due to their formation: as

they leave the region of the arc, their uprush through the material, if it be finely ground, causes channels, upsets the ration of carbon and lime, and sweeps the finest particles, in the form of dust, out of the furnace, and if this be allowed to escape into the factory, the caustic nature of the lime and the grit of the coke not only are dangerous to the health of the workpeople, but injurious to the machinery, driving belts and the working parts of the machines soon showing their action, and it is for this reason that direct driving should always be employed where possible in a carbide factory.

Injurious effects of over gas production in the furnace

Dust and its drawbacks

The dust nuisance may be attacked in several ways. Where it is possible granulating instead of grinding, and the use of closed furnaces from which the gases can be led away and utilised for lime burning or other heating purposes, are the simplest solution, the same result being obtained by the use of briquettes of mixture, and the use of the gases for preheating, as in the Landin and Pictet processes.

How to avoid the dust and gas trouble

In crucible furnaces, such as the improved Willson and Gin & Leleux, the gases are escaping from the small vent-holes provided at the back and front of the crucible, and the trouble is not so easily dealt with.

Special arrangements for minimising the disadvantages

With the improved Willson crucibles used at Foyers, a sheet-iron hood is arranged at each end of the furnace in connection with a vertical sheet-iron shaft of considerable diameter which leads up well above the roof level. This acts not only in carrying off the gases, but also as a settling chamber for particles of mixture of sufficient size to be again used in the furnace, as with the slow current existing in these uptakes the coarse particles readily settle into bins at the bottom of the shaft.

Foyers arrangement

In the Gin and Leleux furnace, the gases escape from a number of small pipes sunk in the brickwork

Gin & Leleux's Ventilators

of the crucible casing, which lead off the gases in such a way as to prevent the presence of a large volume of gas at one time, which would give the risk of an explosive mixture.

From these openings the gas is led into a depositing chamber connected with an uptake flue, or, where this is not convenient, an aspirating fan.

Commercial sizes for Carbide

The carbide sent out has to be broken up in order to suit the purposes for which it is intended: for large generators, pieces the size of an egg and up to the size of the fist are convenient, whilst for some automatic generators and for bicycle lamps granulated carbide is wanted. At some works standard sizes are adopted, a convenient classification being—

Lumps . .	5 to 10 cm. . .	2 to 4 inches.
Large nuts .	2 to 5 cm. . .	1 to 2 inches.
Small nuts .	1 to 2 cm. . .	$\frac{1}{2}$ to 1 inch.
Granulated .	5 to 10 mm. . .	$\frac{1}{5}$ to $\frac{2}{5}$ inch.
Siftings . .	more or less fine powder.	

The breaking up of masses of Calcium Carbide

The hardness of calcium carbide is so great that a very large amount of force has to be used to break it. And when this is done by hand labour or by machines of the stonebreaker type, a large amount of waste results from the formation of powder and dust. It has been found, however, that this waste is largely reduced when crushing machinery of the right type is employed, as, if a piece of carbide be subjected to a strong squeeze instead of a blow, it splits along the cleavage of the crystals and readily falls to pieces.

Crushing machinery

Speyerer, of Berlin, who has devoted considerable attention to carbide-making machinery, constructs crushers on this principle, which reduce the loss in dust and fine particles to from 5 to 10 per cent., whilst with the old methods of breaking it was often more than double that amount.

Loss from Carbide dust in breaking

It is manifest that the production of any large quantity of "smalls" in breaking up the carbide is a

serious loss, as if it be mixed with fresh material and put back in the furnace, the finely divided particles expose so large a surface to the action of air that by the time the mixture has been made up and has again reached the arc, the dust has probably returned to the condition of lime and carbon once more, whilst if a special small furnace be employed for again fusing the waste, a poor carbide results, owing to dissociation of some of the original carbide.

Utilisation of Carbide dust and "smalls"

At present the best method of utilising the dust and "smalls" made in this part of the operation is that proposed by Lewes, which is to break up the carbide whilst still fairly hot and to mix the dust as it falls from the sieves with tar which has been boiled for a sufficiently long period to expel all water. The tar is used in just sufficient quantity to make the mass pasty, and then the mixture is pressed into moulds and heated in a muffle furnace to a dull red heat, which causes all volatile hydrocarbons to distil out from the tar and leaves the carbide particles bound together by spongy carbon and in such a condition that water can readily permeate through the mass and decompose the carbide present. These carbide briquettes can be made of any size and in any form, and as the gas is disengaged from them in a steady stream, they are eminently adapted for use in bicycle lamps, table lamps, and small generators, and yield about 4 c. ft. of acetylene per lb.

Carbide briquettes

Ingot Carbide and its treatment to prepare it for the market

In making ingot carbide, the ingots as they leave the furnace have to stand some time to ensure solidification throughout the whole mass. They then have the worst of the crust removed by a hammer, and are broken by hand to a size that enables them to be put in the crusher. This can be so regulated as to give a fairly uniform size of product, and it is found most economical, where small sizes are required, to reduce the size of the lumps by successive operations.

It is practically impossible to avoid the action of the atmosphere during this part of the operation, and closed crushers or mills are not advisable, as an explosive mixture of low igniting point is rapidly formed, and a piece of hot carbide or a spark from the jaws might easily give a most dangerous explosion. For this reason also the crushing room must be well ventilated, and everything done to prevent carbide dust, which affects the workmen's eyes and respiratory organs.

The blending of ingot and crust

The ingot as it leaves the furnace contains about two-thirds of its weight of pure crystalline carbide, often of 98 to 99 per cent. purity, whilst the remaining one-third varies from 75 to 50 per cent. of purity, as the quantity of unconverted material grows larger and larger as it nears the surface of the mass, and has been further from the zone of strongest action in the furnace. It would be practically impossible to entirely separate the perfectly pure ingot from the less pure outer portions, save by breaking up the whole mass and hand-picking the most perfectly crystallised portions. And the most reasonable procedure is to pick out as far as possible the poorest portions of the ingot, and to blend the remainder so as to give a commercial carbide yielding an average of about 5 c. ft. per lb. of carbide (315 litres per kilo.), at ordinary temperatures, *i.e.* of about 85 to 90 per cent. purity.

Drawbacks to blending

The only trouble consequent upon such procedure is that, owing to want of care in blending the mixture of ingot and crust, a sample of carbide containing an undue proportion of the poor carbide is occasionally sent out, and causes dissatisfaction.

Run Carbide

With run carbide this trouble disappears, but, as has been before pointed out, in order to get the carbide sufficiently liquid to run at a temperature that does not cause excessive damage to the furnace and dissociation of some of the carbide itself, an excess of

lime has to be used, and this remains dissolved in the carbide, with the result that a standard of 5 c. ft. per lb. is rarely reached.

A standard quality for commercial Carbide

The question of fixing a standard quality for commercial carbide has been several times raised, and the outside public has wondered why so apparently easy a question to solve should have remained unsettled. But the crux of the question is that the makers of ingot carbide can produce a carbide up to a standard of 4·8 to 5 c. ft. of acetylene per lb. of carbide (300 to 315 litres per kilo.) under the most economical conditions of working with the class of furnaces they employ, and therefore insist upon a high standard of purity being fixed, a view which the public, who have to pay a considerable portion of the freight, endorse, whilst the manufacturers of run carbide, owing to their having to add a slight excess of lime as a flux, would find it more economical in their furnace practice if the standard more nearly approached 4 c. ft. per lb. (250 litres per kilo.).

The unit of gas production to form the basis for price of Carbide

This trouble could be overcome if, instead of selling carbide by weight, it were to be sold at so much a unit of gas-producing power, the price being so calculated as to allow for the extra freight, etc., incurred by using a low quality carbide.

If this were done, it would of course be necessary to rigidly define the form of generator in which the gas-yielding power of the carbide should be determined, and also the way in which the samples should be taken; but when once these details were fixed, each manufacturer would be free to use his plant to the most economical advantage, whilst the consumer would get what he paid for.

Run Carbide

It must be borne in mind that these remarks apply only to the ordinary commercial run carbide, and that it is possible, where carbons are cheap, to make a very fine run carbide by simply adding more carbon

to the mixture. Indeed, one of the purest carbides analysed by the author was a run carbide from Froges; but directly this is done any economy over the ingot process is entirely swamped.

The cost of power works

It is practically impossible to give an idea of the cost of erecting power works, but in many cases the owners of water power are offering it at so much per H.P. per year, which often gives rise to a grave misconception as to the cost of making carbide. Suppose, for instance, that 1,000 water H.P. is offered at £2 per H.P. per year, including pipes and all the other permanent outlay other than machinery. The turbines, dynamos, conductors, and transformers would cost in round figures £7,500, and, as only seven-tenths of the water power at most could be transformed into electrical H.P., the cost per E.H.P. per year would be—

The cost of a 1,000 H.P installation

Cost per E.H.P. per year

	£
Rental	2,000
Interest, depreciation, and repairs .	750
Wages	220
Oil, waste, stores, etc. . . .	110
Cost of 700 E.H.P.	£3,080

or £4 8*s*. per E.H.P. per year.

so that the price of the water power is more than doubled by the time you have got the current to the furnace.

Cost of Carbide per ton on the above basis

If the works were so situated that cheap and good coke and lime can be obtained, the cost per ton of the carbide would be approximately as follows:—

	£	*s.*	*d.*
Labour, including repairs . .	1	5	0
Carbon electrodes . . .	0	15	0
Materials for repairs . . .	0	4	0
Stores	0	1	6
Coke at 12*s*. 6*d*. per ton . .	0	8	9
Lime at 12*s*. per ton . . .	0	12	0
Grinding	0	4	0
Power	4	8	0
	£7	18	3

say £8 per ton of packed carbide.

Where the price of coke and lime does not vary widely from the prices in the above estimate, a fair approximation may be obtained as to the cost of manufacturing carbide per ton by adding £3 10*s.* to the cost per E.H.P. per year.

With a plant of 5,000 E.H.P. and the best labour-saving conditions, this price could of course be reduced by nearly £1, but the prices mostly given for the production of calcic carbide are as a rule too low.

Cost of making Carbide at Meran

L'Eclairage Electrique contains the following summary of the cost of carbide at Meran:—

Material

1. *Materials.*—1 ton of carbide requires 940 kgr. CaO and 650 kgr. carbon. The limestone costs per ton, 2 fl. The lime furnace produces 6,000 kgr. of lime with a consumption of 1,800 kgr. coal. The price per ton of lime in the work is 10 fl., the coke used for making the carbide costs 20 fl. per ton.

Electrodes

2. *Electrodes.*—One electrode is sufficient to make 10 tons of carbide, and the cost of making them being 80 fl., the cost per ton of carbide will be 8 fl.

Energy

3. *Electric Energy.*—For the production of a ton of carbide 6,400 E.H.P. hours are wanted. The H.P. calculated at 25 fl. per year gives—

$$\frac{25 \times 6400}{24 = \ 300} = 22{\cdot}9 \text{ fl.}$$

The different machines for transporting and lifting the materials and product require 200 E.H.P. The daily production of carbide, being 6·5 tons, gives—

$$\frac{200 \times 24}{24 \times 300} \quad \frac{\cdot 25}{6{\cdot}5} = 2{\cdot}5 \text{ fl.}$$

Works expenses

4. *Works Expenses.*—21 workmen are employed during the day and 9 at night. The wages 1·75 to 2 fl. per day, the total being 60 fl. per day, therefore, per ton, 9 fl.

Cost of Packing

5. *Packing.*—The cost is 2·50 fl. per ton direct.

Deprecia-tion

6. *Depreciation, etc.*—Per ton, 12·10 fl.

General expenses

7. *General Expenses.*—

	fl. per ton.
At works: directors, manager, rates, patents, etc.	11·000
At works: various expenses . .	1·400
At offices: Directors of the Board, office expenses, etc. . . .	12·500
	25·00

Carriage

8. *Cost of carriage* from the works to the railway station is 1·50 per ton.

Maintenance

9. *Maintenance* requires 7,500 fl., *i.e.* 3·75 fl. per ton.

Total cost per ton

The cost of production, taken as the sum of the above items, will be 95·05 fl. or £7 18*s.* 5*d.* per ton of packed carbide.

List of the Carbide works of the world

The following is a list of carbide works at present running or in course of construction:—

CANADA.

Canada

	Water Power.
Th. L. Willson, St. Catherine's, Ontario . .	12,000
Shewangen Falls	5,000

UNITED STATES.

United States

Union Carbide Co., Chicago, Ill., Soo Falls, Saulte St. Marie, and Niagara Falls . .	25,000

GERMANY.

Europe Germany

Aluminium Ing. A. G., Rheinfelden . .	3,000
Electrochemische Works, Rheinfelden . .	2,500
A. G. für Holzindustrie, Lechbruck . . .	1,000
Portland Cement Works, Lauffen-a-M. . .	1,000
Versch. Versuchswerke, Frankfort-a-M., Neheim, U.S.W.	—
Schilling & Gutzeit, Guttstadt, Wormditt .	—

ENGLAND.

England

Acetylene Illuminating Co., Foyers, Scotland	3,000

France

FRANCE.

	Water Power.
Bertholus, Charles, Bellegarde sur la Rhone	1,200
Cie Française des Carbures de Calcium, Sechilienne sur la Romanche	1,200
Cie Général d' Electrochimie, Bozel, Savoy .	4,000
Cie des Salins du Midi, Salies du Salat . .	300
Corbin & Cie, Chedde, Haute Savoie sur l'Arve	2,000
Gayral, Albas sur le Lot	450
Omnium Lyonnais, Arudy sur le Gave d'Ossau	2,000
Mr. L. Robert, La Bathie, L'Arbine, Savoy .	1,250
Rochette Frères, Epierre, Savoy . . .	1,200
Société de Carbure, La Bastide de Levis. Tarn	350
Société des Carbures Métalliques, Paris, Notre Dame de Briancon	3,000
Société Electrochimie du Giffre, Bellegarde sur la Valserine	500
Société Electrométallurgique Française, Froges, Isere	600
Société Electrométallurgique Française, La Praz sur l'Arc, Savoy	600
Société Electrométallurgique Française, Serres, Hautes Alpes, sur le Buech	640
Société Electrométallurgique du Giffre, Micussy, Hoch Savoyenne, sur le Giffre .	10,000
Société L'Acétylène, Ste Beron, Isere . .	2,000
Société des Forces Motrices du Haur Gresivandan Chapareillan, Isere, sur le Cernon	800
Société Hydroélectrique des Pyrenees, Le Castelet, Ariege	2,500
Société Usines Electrochimique de Crampagna. Crampagna, Ariege	600
Cie Internationale de Carborundum, La Bathie, Savoy	1,250

		Water Power.
	ITALY.	
Italy	Cav. F. Giorigi, San Marcel, Oberitalien	700
	Ing Carlo Mongini, Poggio Misteto, Distrikt Rieti	150
	Societa Italiana del Carburo di Calcio, Rome	2,000
	Le Marmore Terni, Ivrea	1,000
	NORWAY.	
Norway	Aktieselskabet Hafslund in Hafslund bei Sarpsborg	5,000
	Aktieselskabet Carbidindustrie, Sarpsborg	1,500
	Notodden	2,000
	AUSTRIA.	
Austria	Acetylene Gas A. G., Wien, Meran	2,400
	Allg. Carbid und Acetylene Gesellsch., Matrei, Tyrol	2,000
	Aluminium Industr. A. G., Kend bei Gastein	4,000
	Bosnische Electrizitats A. G., Jajce, Bosnia	5,000
	Krasper, Lobhowitz	450
	Societa veneta di Electrochemica Paternion, Karnten, A. von Supak, Sebenico	600
	RUSSIA.	
Russia	A. G. Electrizitats, Warsaw	1,500
	Hämeskosky Aktiebolag, Wiborg, Finland	2,000
	SWEDEN.	
Sweden	A. G. de Laval, Elektrica Smalt Ugen Trollhatten	3,000
	Alby Calcium Carbid Aktiebolag	6,000
	Sp. åmforseg Orebo Elektriska Aktiebolag	2,000
	Mânsbo Stockholms Superfosfat Aktiebolag	2,000
	FINLAND.	
Finland	Hamekoski Aktiebolag	3,000
	Imabro Aktiebolag	5,000

SWITZERLAND.

Switzer-land

	Water Power.
Aluminium Industrie Akt. Ges., Neuhausen .	
Neuhausen Works	3,000
Elektrizitatswerk Klosters	—
Elektrizitatswerk Lonza in Gampel . .	5,000
Schweizerische Gesellsch. für Elektrochemische Industrie, Bern :—	
Works Luterbach, Solothurn . . .	570
Thusis, Graubunden . . .	3,500
Société d'Electrochimie, Usine du Day, Vallorbes	—
Société Génévoise d'Electricité et des produits chimiques, Vernier, Genf	1,200
A. G. Elektrizitatswerke, Wynau . . .	—
Siemens & Halske, A. G., Berlin, Wynau .	750
Via Mala	—
Walliser Industrie Gesellsch., Zurich, Works Vernayaz	900

SPAIN.

Spain

Mas Revertes y Cia., Barcelona	500
Société des Carbures Métalliques, Paris, Barga	2,500

Attempts to make Carbide without Electricity

As soon as calcium carbide began to assume a position of commercial importance, attempts were made to produce it without the use of electricity, and exhaustive experiments were made to devise a process which should be less expensive than is the case when the temperature of reduction of the lime and formation of carbide takes place in the electric furnace. As has before been pointed out, the temperature necessary to reduce lime to metallic calcium, when carbon alone is the reducing agent, is somewhere about 2,700° C., whilst the temperature of fusion is probably 3,000° C., and it is clear that if such a temperature is to be attained by other than electrical means, considerable

difficulties must at once arise in finding a material sufficiently refractory to withstand the necessary temperature. It seems probable, however, that advantage might be taken of the nascent condition in bringing about the desired result, and many experiments were made in this direction.

By heating Calcium Tartrate

Zino states that if crude calcium tartrate, such as is obtained in the sediment in wine casks, is heated to about 499° C. (930° F.) in a cast-iron retort raised to the required temperature in an ordinary furnace, a grey spongy mass is left which causes brisk effervescence on contact with water, whilst the gas evolved burns with a brilliant light, and he concludes the gas must be acetylene. Even supposing, however, that calcium carbide could be made in this way, the price of the calcium tartrate would prevent its ever competing with carbide made in an electric furnace.

By passing Hydrocarbon vapours over incandescent lime

Other attempts to reduce lime by nascent carbon have also been made, one process being to pass the vapour of hydrocarbons through lime heated to a high temperature, the decomposition of the hydrocarbon liberating carbon in a condition of activity, whilst the reducing action is aided by the nascent hydrogen. Experiments on a small scale seem to show that this might be possible, but the inventors of the process found on trying to repeat their work on a large scale that the practical difficulties were insurmountable.

By using a metal having a strong affinity for Oxygen

It is perfectly well known that if a temperature commercially practicable is to be used, some metal with a strong affinity for oxygen must be employed to reduce the lime to calcium before combination with the carbon will take place. Such metals as will do this, potassium, sodium, and magnesium, or even zinc, are however too costly, and if a process were devised in which the vapours of such metals were liberated by reduction from their salts, and were made to

interact with carbon and lime at a high temperature it could only be made commercially possible either by a large demand being created for the bye-products, or by these being capable of being cheaply worked up and used over again. In either case the probabilities are that the cost would exceed that of making carbide by electricity generated by water power.

By using ordinary combustion heat

Many attempts have also been made to manufacture carbide directly from lime and carbon by direct heating processes in which the inventors hope to obtain the necessary temperatures, but most of these attempts have not passed beyond the paper stage. In one case, however, small works were erected in the neighbourhood of London, and an attempt was made to obtain the carbide by first producing a gaseous mixture by alternately causing hydrocarbon vapour and steam to pass through a series of retorts containing hydrated oxide of iron, which was alternately reduced by the hydrocarbons with the formation of steam methane and hydrogen, and in its reduced form was then re-oxidised by the passage over it of steam, which set free hydrogen. The gaseous mixture so obtained having been stored in a holder was used to feed a number of converging blowpipe burners arranged in a furnace in such a way as to heat a mixture of lime and carbon which was fed down to them. It is of course manifest that such a process could never be successful, as if a piece of carbide be taken and heated in the oxy-hydrogen blowpipe itself, not only does no fusion take place, the temperature being insufficient, but the carbide is decomposed, and after some heating simply remains as carbon and lime containing a little calcic carbonate.

The Woodside process

No fuel containing hydrogen as the main constituent could be used in a process of this kind, as although the temperature may be above the dissociating point of the water formed during com-

bustion, it is manifest that the formation must take place in order to give the heat, and this instantaneous production would be quite sufficient to break up any carbide produced.

Liquid air and its possible application to Carbide making

During the past few years the beautiful researches of Linde have made liquid air a commercial possibility, and by allowing some of the nitrogen to boil off from this, a liquid evolving a gas richer and richer in oxygen can be obtained, and there is no doubt that if this were employed for burning purely carbonaceous fuel the requisite temperature might be attained, but the trouble as to the life of the furnace would still exist.

Borchers' process

Dr. Borchers has patented a process for making calcium carbide by mixing together coke and lime into a paste with liquid air, and igniting the mixture by a fuse; but although this process has been talked of for some time, no definite results are yet published, the inventor being anxious that the public should withhold their judgment on his process until the necessary patents to protect it have been taken out. Under these conditions it is of course impossible to offer an opinion as to the feasibility of such a method, but it is hard to believe that it could ever be a commercial success.

Bergemann's Oxygen furnace

Bergemann has patented a furnace for the production and melting of such materials as calcium carbide without electricity, hoping to obtain his result by the combustion of carbon in oxygen, and in order to do this he uses an oven surrounded by a water-jacket, and produces his oxygen by a continuous manganese process. This oxygen is then used for the combustion of coke or liquid fuel.

Carbide as a bye-product

Attempts have also not been wanting to make carbide as a bye-product, and a process which has been much talked about is one proposed by Hartenstein for the manufacture of carbide from blast furnace

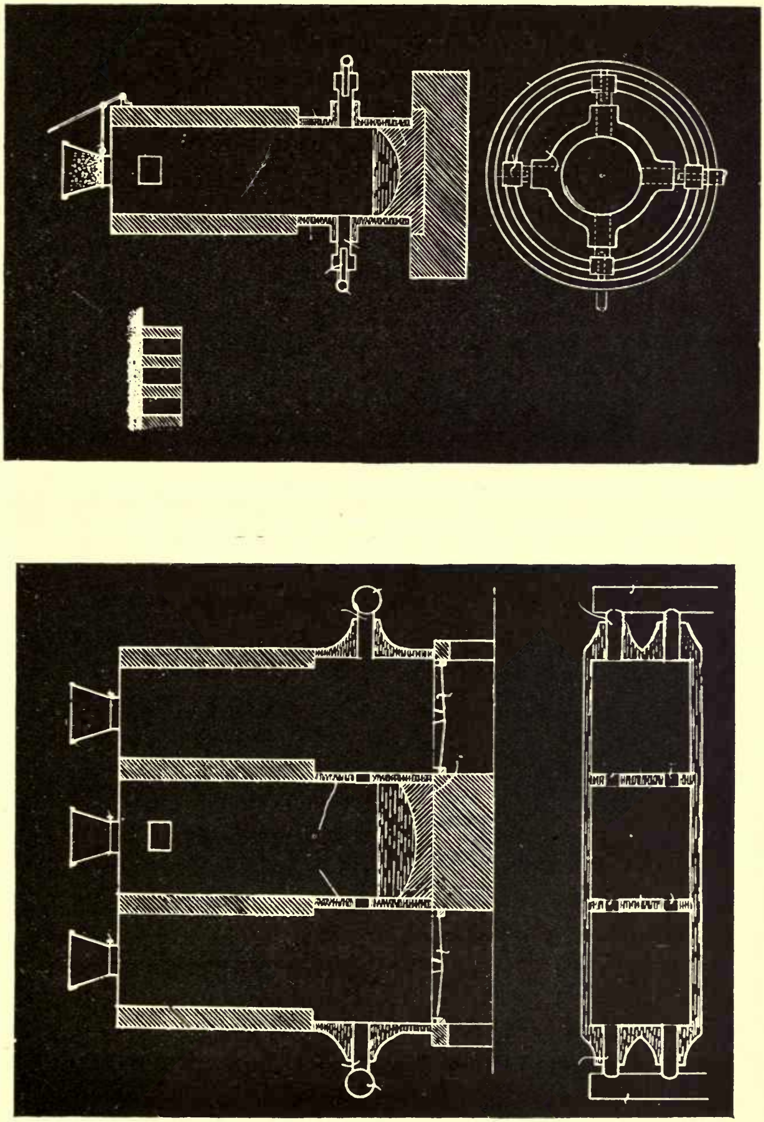


FIG. 90.—BERGEMANN FURNACES.

slag and coke dust. A description of the process is here reproduced in the inventor's own words :—

Blast furnace Slag

"For every 2,000 lbs. of pig iron there are obtained 1,500 lbs. of slag. This is not only a waste product, but its removal is usually an expense to be charged with the cost of the iron. Blast furnace slag is composed of from 50 to 55 per cent. of lime, 25 to 28 per cent. of silicon, 16 to 18 per cent. of aluminium, and a small proportion of other substances, varying according to the composition of the ore reduced and the limestone employed as a flux. By using the processes mentioned this slag is combined with carbonaceous material, such as coke, and a new product is obtained, which is known as 'carbolite.' On bringing carbolite into contact with water or other liquid, a gas is instantly generated, which, when used in suitable burners, gives a beautiful white flame of great steadiness and remarkable luminosity."

Carbolite

The process claimed for making Carbolite

The method of producing carbolite is as follows: "Slag, being a combination of all the non-volatile substances contained in the charge, except the iron, and being lighter than smelted iron, floats on top, and is drawn off through an aperture in the furnace placed at the upper line of the molten iron into suitable receivers so constructed as to retain the great heat. Being at a very high temperature, it is almost as fluid as water, and by means of great ladles operated by hydraulic power it is passed from the receivers into converters, similar to those used in manufacturing Bessemer steel. Except that the tops are somewhat closed, the opening being much smaller than the central diameter, these converters may be likened to elongated iron kettles hung on hollow shafts or trunnions, so as to easily turn or tip. Through these hollow shafts or trunnions iron pipes are run leading to and connected with a number of small tubes that perforate the bottom of the converter. These pipes

and tubes are so arranged that finely pulverised coke can be fed and forced through them. Before the slag is poured into the converters a strong gas blast is forced through the pipes to keep the molten mass from running into and filling them up. As soon, however, as the slag is poured into the converter, pulverised coke is fed into the pipes, and by the gas blast carried through and forced into the molten mass. This is continued until the slag is thoroughly impregnated with the coke. To ensure uniform mixture the converter can be tipped backward and forward as desired, thus increasing the agitation.

Treatment of the Slag

"When the mixture is complete, the converter can be turned on its shaft, so as to cause the mass to flow between a series of carbon bars or electrodes that serve to introduce a powerful electric current. Coke is an excellent conductor of electricity, while slag is highly resistant. The result is that the particles of slag in connection with the particles of coke form innumerable miniature electric arcs, producing a most intense heat within the mixture. In the course of about twenty minutes the mass becomes so superheated that the slag is deoxidised, and becomes fused with or carburetted by the coke. When this fusion is effected the material is finished. It is then poured into moulds of any desired shape and size. When cool it is of crystalline formation, has a metallic glitter, and is nearly twice the weight of coal. The finished product, carbolite, can be kept indefinitely, and transported without difficulty. It is impervious to almost everything except water. Each pound of good carbolite will produce 5 cubic feet of gas, and each cubic foot of this gas is equal in illuminating power to about 15 cubic feet of ordinary coal or water gas.

Conversion of the Slag and Carbon into Carbolite

Alleged yield of gas from Carbolite

"By a little calculation it will readily be seen that at \$50 per ton, or 2½ cents per lb., 35 cents worth of

carbolite will produce as much light as 1,000 cubic feet of ordinary coal gas costing $1, and the same amount of light by sixteen-candle-power incandescent electric lamps at 1 cent per hour each would cost upwards of $2.

The Carbolite plant

"The construction of a carbolite plant is almost identical with that of the Bessemer portion of a steel plant, except that electrical heat is also used. The converters can handle three or more tons at a single charge, being manipulated by hydraülic power, as are also the cranes and ladles. In fact, nearly all the highly developed mechanism of the modern steel plant is directly adaptable for the manufacture of carbolite. The most favourable conditions for the production of carbolite would be in connection with the manufacture of pig iron and coke. In a combined plant, not only could the slag of the blast furnace be made valuable, but the immense volume of gases from the furnaces, converters, and coke ovens, together with the now wasted sensible heat, could all be transferred into mechanical energy ample to provide for all power requirements, and without the expenditure of a penny for fuel. The famous water power of Niagara cannot compete with this for cheapness, for with fuel furnished without cost, water power cannot compete with the steam engine or gas motor."

Possibilities

This description is given as the idea is existent in England that the process is being worked in America, whilst inquiries from America as to how the process is progressing in Europe suggest that it is still looked upon there as possible. Granting Hartenstein's assumption that slag is composed of from 50 to 55 per cent. of lime, 25 to 28 per cent. silica, and 16 to 18 per cent. alumina, and that this could be converted by the method proposed into calcic carbide, aluminium carbide, and carborundum, it would be possible to obtain from such a body a mixture of methane and

acetylene which would be valuable for illuminating purposes, if decomposed in a generator the temperature of which rose to the point found in some of the worst forms existing; but even under these conditions carborundum would remain undecomposed. Hartenstein further goes on to calculate the cost of this wonderful material, which he brings out at $1·75 per ton; and as the material, according to him, is to produce 5 cubic feet of gas per lb., each cubic foot of which is to equal in illuminating value 15 cubic feet of coal gas, the millenium with regard to the generation of light seems to be rapidly approaching.

The packing and storage of Carbide

No matter how carbide may be made, certain precautions are necessary in packing and storing it. Being acted upon with considerable rapidity by moist air, with evolution of acetylene and formation of a surface coating of lime over the carbide, it is manifest that it must be protected from this deleterious influence, and it is now always packed at the works in strong iron drums in large quantities, or in hermetically sealed tins in smaller bulk.

Carbide drums

It is of the greatest importance, however, that these vessels should be of sufficient strength to withstand the rough usage inseparable from railway transit. The tendency on the Continent is to use tins of too flimsy construction, which, although having the advantage of cheapness, undoubtedly give rise to the risk of being stoved in by a fall, or by the placing of heavy packages upon them. The carbide itself is so heavy that strength in the vessels is an absolute necessity, and where tins are used they must be encased in wooden boxes for transit. They should be so made as to be practically air-tight, a condition which can readily be attained by a screwed lid or by a clamp; and it is as well that the maximum contents of each drum should not exceed 1 cwt., and iron or steel is undoubtedly the best material of which they can be made.

Packing Carbide drums

The carbide after breaking at the works is generally packed into the drums whilst still warm, the drum itself having been exposed to a temperature sufficient to preclude the possibility of its containing moisture in its interior; and it is manifest that, under these conditions, when the tin is closed, the contraction of the air in the spaces between the pieces of carbide would lead to a diminution in pressure, and cause a sucking in, through any small leak, of air containing moisture. The risk of this, however, is not great, and could be entirely obviated by a screw cap in the lid, to which a drying vessel containing rough calcic carbide could be attached until the tin had cooled down to atmospheric temperature.

It is important that when sent out the drum should be quite full of carbide, and no large air space left above its surface, and the carbide should never be packed into the drum with organic matter. In America very large drums were at one time used, and wheat chaff was put in with the carbide to fill the interstices; but when the carbide had been used, this packing was often thrown on dust-heaps, and, containing powdered carbide, sometimes caught fire when wetted by a shower of rain.

Lid valves for Carbide drums

Carbide drums are now being made on the Continent, in which the lid is fitted with a small valve, which allows the escape of any gas made from within, and so prevents undue pressure within the vessel itself, whilst it stops any access of air from without.

The forms of the tins and drums vary considerably, one very useful shape being that employed by the Magyar State Railway in Hungary, these tins being about the size and shape of an ordinary milk-can, and closed hermetically by a lid held in position by a clamp.

Storage

There is no more risk in the storage of calcium car-

bide than there is in storing any other inert material, provided it is packed dry and warm in hermetically sealed drums, so as to render it impossible for it to come in contact with water or moist air.

Carbide stores

The real risk is in the removal or redistribution of the material, as after opening a drum it may not be again properly closed, and if the drum be left in this condition in the moist air of an ill-ventilated cellar, it is quite possible for a slow generation of gas to take place, and an explosive mixture to be formed by its accumulation.

All carbide stores should be thoroughly ventilated and above ground, and when this is the case all danger is practically done away with.

The colour of Calcium Carbide

The calcium carbide as formed in the electric furnace is a beautiful crystalline semimetallic-looking solid, having a density of 2·22, and showing a fracture which is often shot with iridescent colours owing to the formation of excessively thin films of oxide on its surface.

Moissan's researches in pure Carbide

Moissan, however,[1] has shown that its colour is entirely due to impurities in it, chiefly iron, and that when the materials from which the carbide is prepared are perfectly pure, the true calcium carbide is white and transparent.

The preparation of pure Carbide

He obtained absolutely pure calcium carbide by the action of heat on a compound obtained by acting upon calcium ammonium with acetylene, which yielded a compound $C_2Ca\ C_2H_2\ 4NH_3$, a body which becomes incandescent on contact with water, chlorine, carbon dioxide, or sulphur dioxide, and dissociates when heated, yielding pure calcium carbide. Moissan also found that if calcium hydride, CaH_2, or calcium nitride, Ca_3N_2, be heated with pure carbon, thin plates of white transparent calcium carbide are obtained; and he proved that the colour of the commercial carbide was due to iron, as by fusing some pure snow-white carbide in a graphite crucible, with

[1] *Compt. Rendu*, 1898, 127, 917, 918.

a small trace of iron oxide, in the electric furnace, he obtained ordinary commercial carbide.

Bullier & Perrodil's researches on the foreign matter in Calcium Carbide

Bullier and Perrodil[1] divide the impurities which are to be found in commercial carbide into two classes: those which are not decomposed by water under ordinary conditions and those which are. The first class consists of graphite, partly resulting from the action of the heat in the electric furnace on the carbon, and partly formed by the dissociation of calcium carbide from over-heating; carbide of boron, formed by the action of carbon on boric acid, occurring in the coke; carbide of silicon, or carborundum, from the action of carbon on the silicic acid present both in the lime, ash of the coke, and electrodes; and silicides and carbides of various metals, the oxides of which are in the lime and coke ash. They give, as the impurities of the second class, substances evolving compounds of phosphorus when acted on by water, which yield phosphorous pentoxide when burnt with the gas; aluminium sulphide, which yields sulphuretted hydrogen; organic sulphur compounds, and metallic nitrides, which under the influence of pure or alkaline water set free ammonia.

The combinations of Silicon in Calcium Carbide

Lechatelier[2] pointed out that in commercial carbide, besides the calcium and carbon, there exist silicon and iron; and although it would be possible for the iron to be united with any of the three other bodies, it is only in combination with the silicon as iron silicide Fe_2Si, the silicon only combining with the calcium or carbon according to whether the one or the other is in excess. Thus when carbon is present in abundance the hexagonal blue crystals of carborundum are formed; but if the calcium be in excess, calcium silicides are produced as small grey metallic crystals, which may be collected from the lime residue by

[1] *Rec. Tech. Ind. de l'Acet.*, 1896, 87.
[2] *Bull. Soc. Chem.*, 3, 17, 193.

washing the lime as far as possible away, and treating the residue with acetic acid.

Silicides of Calcium

It appears that two different calcium silicides can exist, the one scarcely acted upon by nitric acid but rapidly by hydrochloric acid with formation of a grey insoluble substance; the other, which is easily dissolved by nitric acid and acetic acid, gives a white precipitate with hydrochloric acid, which dissolves in potassium hydrate with evolution of hydrogen.

Metallic nodules in Carbide

It is well known that on breaking a sample of carbide metallic-looking nodules are frequently found, and used to be far more frequent in the carbide before the purity of the materials was insisted on than they are at present. These nodules are generally found in a spherical or oval shape, and have evidently separated from the molten mass on the crystallizing of the true carbide.

Some of these were analysed in Sweden and were found to contain

Silicon	26·4
Iron	73·6

corresponding to Fe_2Si_5. These nodules were probably not a compound, and they were found to have slightly magnetic properties.

Lewes[1] noticed that the nodules from carbide differed somewhat in appearance, two distinct varieties being clearly noticeable.

Difference observed in the nodules

(*a*) Grey nodules, not attracted by the magnet, not oxidised when exposed to air or heated as a solid lump in the blowpipe flame. Specific gravity 3·5 to 5·8. In a fine powder some had a very faint garlic-like odour, gained 5 per cent. when heated for half an hour, and attacked platinum when heated on it for some time. These nodules gave no gas when acted upon by water.

(*b*) Steel-like nodules, which were strongly mag-

[1] *Journn. Soc. Chem. Ind.*, 17, 532

netic and became coated with iron rust when exposed to moisture and air for some time, and which gave no gas when acted on by water. Specific gravity 6·3 to 6·8.

Composition of the nodules

Analysis showed that the foreign matter present in the carbide consisted of carborundum or silicide of carbon, metallic silicides, iron, occasionally metallic calcium, magnesium, aluminium, and traces of nitrides, phosphorus, and sulphur compounds. One of the nodules on analysis yielded

Silicon	30·76
Iron	58·06
Calcium	2·65
Aluminium	3·01
Magnesium	0·64
Carbon, etc.	4·89
	100·00

None of these substances gave spontaneously inflammable gases when acted upon by water, but in a few instances a nodule was found which evidently contained magnesium silicide, and which, when powdered and acted upon by hydrochloric acid, gave a few bubbles of spontaneously inflammable gas.

Siliciuretted Hydrogen from nodules

M. C. Gerard, chief of the Municipal Laboratory at the Prefecture of Police, Paris, has also analysed some of these nodules with the following results, and found that these alloys, pulverised and treated with concentrated acid, gave off siliciuretted hydrogen:

Iron	55·027	53·250
Silicon	33·172	31 800
Aluminium	5·579	8·910
Calcium	2·764	4·120
Not determined and loss	3·458	1·920
	100·000	100·000

In some cases it was found that the carbon deposited by holding a cold surface in an acetylene

flame contained traces of silica, and this seems to support the idea that siliciuretted hydrogen may occur in the acetylene, but if it does the amount is so small as certainly to give no danger of spontaneous ignition.

Silica found in the Carbon from a smoking Acetylene flame

A sample of gas which appeared to give a considerable quantity of silica was burnt under such conditions as to allow of the silica being collected; and on estimating the quantity formed it was found to correspond to 0·01 per cent. of siliciuretted hydrogen in the original gas.

Gerard's researches on the residues from Carbide

M. Gerard also carried out a number of extremely interesting experiments upon the products found in the residues left after treating the calcic carbide with water, and succeeded in extracting from them minute diamonds. The residues were as far as possible dissolved in hydrochloric acid, and the insoluble portion separated by filtration and washing with water, and the metallic portions separated by sieving. The finer portions were collected in a filter paper, washed and dried, and were then heated with potash in a silver capsule and the insoluble portion treated with aqua regia. After repeating this drastic treatment two or three times, the residue was put into a separating funnel containing a saturated solution of the double iodide of mercury and potassium, which has a density of 2·9, in which silicide of carbon will float whilst graphite sinks. This silicide of carbon is then purified by being treated several times with concentrated hydrofluoric acid, and after washing is dried, whilst the graphitic bodies are treated and separated with iodide of methylene, which has a density of 3·29. The separation of diamondiferous bodies from the silicides of carbon is effected by a saturated solution of cadmium bromotungstate or iodide of barium and mercury.

The labour entailed in the separation of this

diamond-containing powder may be estimated when it is stated that it was necessary to treat no less than between 700 and 900 lbs. of carbide in order to obtain 15·4 grains of this material.

Proof that minute diamonds do exist in the residue

The evidence upon which M. Gerard bases his assumption that these minute crystals are in reality diamonds, formed at the intense temperature of the arc, is that when they are burnt in oxygen they yield nearly the theoretical volume of carbon dioxide. M. Moissan has failed to find diamonds in the specimens of carbide he has examined, but this is probably due to the quantities worked with being far smaller than those treated by M. Gerard.

Nitrogen in commercial Carbide

The most important scientific researches on the impurities of calcium carbide are probably those made by Moissan,[1] who first noticed the presence of nitrogen in commercial carbide, and found 0·02, 0·12, 0·14, and 0·31 per cent. respectively in four different samples, the same fact being also noticed by Chouard,[2] who found in the residue from carbide 0·24 and 0·4 per cent. respectively. Moissan drew especial attention to the important results which might be obtained by careful research on the residue left after decomposing calcium carbide with water, and in order to more easily examine it the carbide was decomposed by sugar solution, which dissolved the lime as calcium saccharate. The residue left from 10 grams of carbide was filtered, and having been washed with sugar solution and afterwards with water, both solutions being free from carbon dioxide, it was washed with alcohol and finally with ether, and dried in vacuo at 40° C.

Moissan's researches on commercial Carbide

Microscopic examination of the Lime residue

Under the microscope the residue was found to consist chiefly of silicon carbide, calcium silicide, and iron silicide, and also a little lime, graphite, and calcium sulphide. This residue when treated with a 10 per cent. solution of hydrochloric acid loses in weight,

[1] *Compt. Rendu*, 127, 457. [2] *Zeit. f. Calc. Acet.*, 2, 347.

iron calcium and a little of the aluminium and calcium sulphide with traces of phosphorus going into solution whilst the silicon carbide and the graphite are not altered.

The residue so obtained was again acted on by concentrated hydrochloric acid, iron calcium and silicon dissolving, and the different amounts dissolved by the solvents used are shown by the following figures:

Action of Hydrochloric Acid on the Lime residue

Action of sugar solution .	3·40	5·3	3·2	3·9	3·4
„ 10 per cent. HCl	2·10	1·9	1·5	2·4	1·4
„ Conc. HCl . .	1·70	1·7	1·4	2·2	1·1

Combinations of Silicon in Lime residues

Silicon occurs principally as silicon carbide; the compound is easily recognised under the microscope, the hexagonal blue crystals being very characteristic. Silicon is also met with as calcium silicide, as stated by Lechatelier, though fine nodules of metallic fracture are always present containing iron, carbon, and silicon. Ramsden[1] also noticed the presence of silicon crystals.

Moissan could not obtain spontaneous ignition due to the presence of siliciuretted hydrogen, but found that the gas was set free by the action of concentrated hydrochloric acid on the residues, owing to the decomposition of calcium silicide.

Presence of Calcium Sulphide in the residue

Sulphur was present as aluminium and calcium sulphide. Calcium sulphide was shown to be present in certain residues obtained by the action of sugar solution by adding, when under the microscope, a solution of lead acetate rendered slightly acid by acetic acid. The white particles of calcium sulphide then became completely black. With water containing calcium hydrate the filtrate did not give a black precipitate, it therefore contained no calcium sulphide. All the carbides tested, however, gave, in the presence of much water, a lime sludge, the clear solution of

[1] *Proc. Roy. Soc.*, Edinburgh, 1880, 20.

which gave with lead salts a black precipitate containing sulphur and phosphorus.

Metallic Sulphides in Carbide

When making calcium carbide the sulphates contained in the lime are reduced, and calcium sulphide, which is not decomposed by water, is formed. On the other hand, when the lime contains aluminium silicate, the silicon forms with the carbon, silicon carbide, and if sulphur be present as sulphate or sulphide, aluminium sulphide is produced, which is decomposed by water with formation of sulphuretted hydrogen. Murlot[1] made aluminium sulphide, Al_2S_3, by the action of antimony sulphide on alumina. This compound was stable at high temperatures. The calcium carbide, therefore, made under these conditicns may contain aluminium sulphide yielding sulphuretted hydrogen in presence of water. The sulphur cannot be present as silicon sulphide, as is shown by the following experiment. Impure aluminium containing silicon is heated in a Florence flask to redness in a current of sulphuretted hydrogen, when fused aluminium sulphide is obtained, whilst silicon sulphide is deposited on the colder portions of the tube. This compound is easily volatile, and therefore would not be present in carbide prepared in the electric furnace.

Aluminium Sulphide

Organic Sulphur Compounds

If calcium carbide contains a certain amount of calcium sulphide it always gives, when decomposed by water, traces of an organic compound containing sulphur. Acetylene evolved from commercial carbide was passed through two wash bottles containing lead nitrate, and was then heated and burnt. In three cases small quantities of sulphuric acid were obtained. The total amount of sulphur in three samples of carbide was 0·37, 0·43, and 0·74 per cent.

Sources of the Iron in Carbide

Iron exists in carbide as silicide or carbo-silicide, and depends mostly on the purity of the coke. In some samples of carbide nodules are found, several c.c.

[1] *Compt. Rendu*, 123, 55.

in diameter, and due very often to the fusion of the iron holder of the electrodes.

Phosphorus is an objectionable impurity; the greater part forms calcium phosphide, but it is also found in small nodules of metallic appearance containing iron and silicon.

Graphite

Certain samples of carbide contain graphite in very small plates, sometimes hexagonal but mostly irregular in shape, and containing silicon and calcium.

Moissan fails to find diamonds in the Lime residue

Finally, the existence of diamonds was investigated by Moissan, who found that the residue obtained by water and hydrochloric acid gave a few transparent particles, none of which burnt in oxygen. None of the samples experimented with contained diamonds.

It was at one time considered probable that crude carbide contained carbides of the alkalies and magnesium; but Moissan has shown[1] that although these metals can be made to form carbides at lower temperatures, they are broken up by the heat of the electric furnace, so that the formation of the carbides of sodium, potassium, and magnesium is impossible under these conditions.

[1] *Compt. Rendu.*, 126, 302.

CHAPTER VII

THE GENERATION OF ACETYLENE

Woehler first decomposes Calcium Carbide and water with formation of Acetylene

IT was in 1862 that Woehler, having made calcium carbide by acting upon an alloy of zinc and calcium with carbon at high temperature, found that the new body formed had the remarkable property of rapidly setting up a double decomposition with water, the carbon of the carbide entering into combination with the hydrogen of the water to form acetylene, whilst the oxygen of the water remained combined with the calcium as lime which was instantly slaked by the excess of water present, a white cloud of calcium hydrate forming in the liquid whilst a certain proportion dissolved.

Reactions taking place during the double decomposition

The reactions taking place are of the simplest character, and may be represented by the equations :—

1.	Calcium carbide.		Water.		Lime.		Acetylene.
	CaC_2	+	H_2O	=	CaO	+	C_2H_2
	by weight, 64 parts		18 parts		56 parts		26 parts.
2.	Lime.		Water.				Calcium hydrate or slaked lime.
	CaO	+	H_2O	=			$Ca(HO)_2$
	by weight, 56 parts		18 parts				74 parts.

Action of Calcium Carbide on Calcium Hydrate

When a small quantity of water comes in contact with an excess of calcium carbide the first reaction is approached, but a certain amount of hydrate is always formed, which on standing is slowly dehydrated again by the excess of carbide.

Until 1892, when Willson made carbide by the hundredweight, the amount produced was so small that the generation of the gas rarely went beyond the scale of dropping a piece of carbide the size of a pea into water and igniting the bubbles that escaped, but in 1892 Venable, who was reporting on Willson's aluminium process, obtained samples of the calcium carbide which was being made at Spray, and in conjunction with Kenan experimented with it in order to determine its composition. The analyses made were of an unsatisfactory character owing to free graphite in the specimens and the rapid vitiation of the carbide in air, but they soon recognized it as a carbide of calcium, and also that the gas evolved on contact with water was acetylene which gave, with ammoniacal cuprous chloride, the distinctive red precipitate of copper acetylene.

Venable analyses Willson's Carbide

It was at once manifest that, as they were obtaining 3·5 to 3·7 c. ft. of this gas from a pound of the carbide, if a use could be found for the gas it might be commercially profitable to use the electrical plant for its production, and attempts were made to burn it at an ordinary gas jet. The flame, however, was red and lurid, and gave so formidable a deposit of soot that its combustion alone was temporarily abandoned. Venable then burnt it in admixture with air at an ordinary bat's-wing jet, and obtained such brilliant results that, in spite of an explosion, the experiments were persevered with during the spring of 1893.

Early attempts to utilise Acetylene as an illuminant

The combustion of a mixture of Acetylene and air

These experiments showed that a ratio of air and acetylene could be fixed at which there was apparently little or no danger of explosion, whilst the mixture could be burnt at ordinary Bray nipples, and gave a magnificent light.

In order to introduce the gas for illuminating purposes, a simple form of apparatus was designed, in which acetylene could be set free by allowing water

The first Acetylene generator

to come into contact with the carbide, and thus it was that the first acetylene generator came to be made.

It was not, however, until the end of 1894 and spring of 1895 that acetylene began to make any headway, even in the land of its birth, but the moment that this point had been reached, and the commercial possibilities of the gas had become apparent, there arose the remarkable burst of activity which has marked the last five years. At the present time, in England alone, some 300 forms of acetylene generators have been patented. About 60 of these have been actually made, and half that number have attained to the dignity of being on sale.

The growth of the generator tribe

Methods of bringing about the action

The generation of acetylene by bringing calcium carbide and water into contact is so beautifully simple that this multiplication of the number of forms of apparatus seems not only unnecessary but hardly credible, yet the English patent list contains by no means all the forms that have been designed, and the Continental and American lists bring the total up to a formidable roll.

Every operation, however, no matter how simple it appears at first sight, is capable of being performed in several ways, and decomposition of the carbide by water may be brought about either by bringing the water slowly into contact with an excess of carbide, or by dropping the carbide into an excess of water, and these two main operations may again be varied by innumerable ingenious devices by which the rapidity of the contact may be modified and even eventually stopped. The result of this is that, although the forms of apparatus utilised for this purpose are all based on the one fundamental principle of bringing about the contact of the carbide with the water which is to enter into double decomposition with it, they have been multiplied in number to a very large extent by the methods employed, in order to ensure control in

Only one principle but many modifications possible, in bringing about the action

working, and to get away from the dangers and inconveniences which are inseparable from a too rapid generation.

Classification of Acetylene generators

In attempting to classify acetylene generators, some authorities have divided them into as many as six different classes; but this is hardly necessary, as they may be naturally divided into two main classes—those in which water is brought in contact with the carbide, the carbide being in excess during the first portion of the operation; and, secondly, those in which the carbide is thrown into water, the amount of water present being always in excess. The first class may again be subdivided into generators in which the water rises in contact with the carbide, in which it drips on to the carbide, and those in which a vessel full of carbide is lowered into water, and again withdrawn as generation becomes excessive.

Automatic generators

Some of these generators are constructed with the view of making the gas only as fast as it is consumed at the burner, with the object of saving the expense and room which would be involved by a storage holder; and generators with devices for regulating and stopping at will the action going on are generally termed automatic, whilst another set of generators merely aims at developing the gas from the carbide and putting it into a storage holder with as little loss as possible, and these are termed non-automatic.

Non-automatic generators

The laboratory equivalents of these types of generator are of the simplest description.

Experimental "Drip" apparatus

The first, or "drip" type, in which water falls on to the carbide, is found in a Bohemian flask of about 16 oz. capacity, Fig. 91, the carbide being dropped on to a thick layer of sand in the bottom of the flask, this being necessary to prevent breakage from the heat generated during the action. The mouth of the flask is then closed by a good cork, carrying in one hole a right-angled delivery tube to carry off the gas, whilst

a dripping funnel with a stopcock is fitted through a second hole. The stopcock can be set to allow the water to pass a drop at a time, and it forms an excellent generator for experimental purposes.

The second or "rising" type, Fig. 92, already exists in

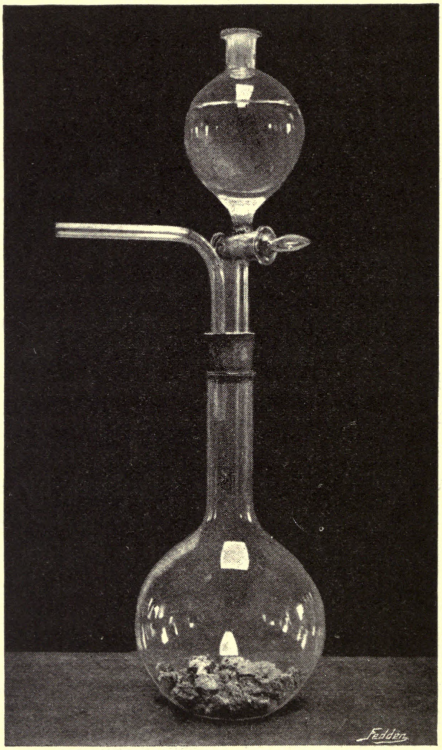


FIG. 91.

Experimental "Water Rising" apparatus

almost every laboratory in the well-known "Kipp's" apparatus used for the generation of sulphuretted hydrogen from ferrous sulphide and dilute acid, or of hydrogen from zinc and acid. To use this for generating acetylene a layer of broken pumice-stone is placed in the central bulb, and upon it the carbide,

care being taken that none of the carbide touches the glass, as otherwise breakage from heat is very likely to take place. The upper bulb, with its tube passing to the lower chamber, is then placed in position, and the lower chamber and upper bulb filled with water

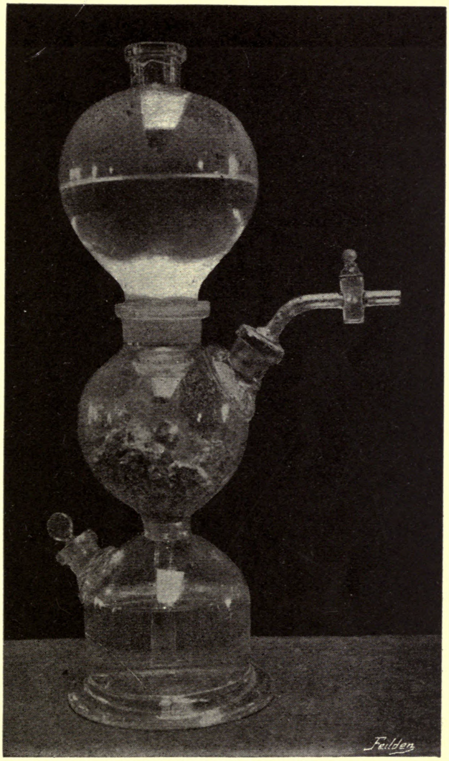


FIG. 92.

by pouring water in at the top and allowing it to drive the air out through the gas outlet.

Working of the Laboratory apparatus

When the lower chamber is nearly full of water the gas-cock is closed, and the apparatus is ready to work. On opening the gas-cock the pressure of the water in the upper bulb drives water up into the central cham-

ber, where it generates acetylene; but when the gas-cock is closed or when more gas is generated than is being used, the pressure created in the central chamber again drives the water down from the carbide.

Experimental form of the "Dipping" apparatus

The third type, in which the carbide, contained in a vessel attached to the bell of the holder, is immersed in

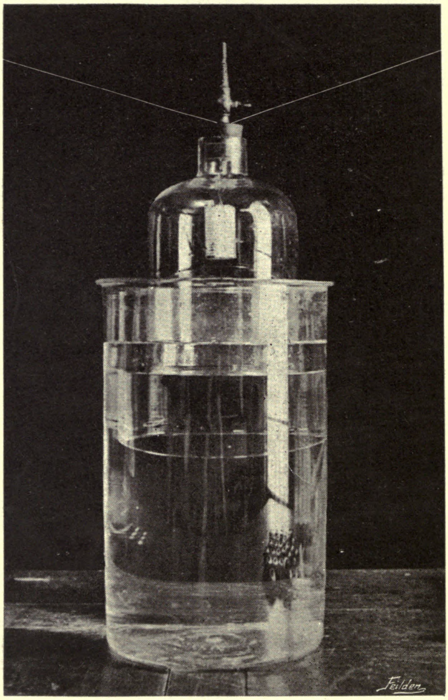


Fig. 93.

the water of the holder tank, and as gas is generated is drawn out of the water by the rising of the holder, is well illustrated by fitting a bell jar, Fig. 93, with a good sound bung, through which passes a tube closed by a stopcock and a small nipple. On the underside of the cork is hung a small cylindrical basket of perforated zinc, of such size as to freely pass through

Method of construction

the mouth of the bell jar, and filled with calcium carbide. The bell jar is placed in a cylinder of water so that the water stands level with the bottom of the tubulure, and the basket is rapidly passed down and the cork pressed in. As soon as the carbide reaches the water gas is evolved, and, filling the top of the holder, causes it to rise. If the gas jet is now lighted the gas burns away, and the holder, re-descending again, plunges the carbide into water and again develops gas, this action continuing until the carbide is all exhausted.

Experimental "Carbide into water" apparatus

The fourth type, which really constitutes the second main division of generators, is that in which carbide is thrown into water, the latter being always in excess. On a laboratory scale this apparatus is best made by taking a conical filtering flask, with side tubulure, and fitting it with a sound cork through which passes a wide tube open at both ends, which terminates inside the flask just below the tubulure (see Fig. 12, p. 60).

Working of the apparatus

Above the cork a piece of indiarubber tubing is slipped over the end of the tube, connecting it with a strong glass flask which is filled with carbide. The filtering flask having been half filled with water, the cork is put into position, and on raising the carbide vessel pieces fall down from it through the indiarubber tube into the water, and the acetylene is evolved.

Heat generated during the decomposition

Even when working on the laboratory scale with quantities of carbide of 100 to 200 grs., it soon becomes evident that considerable heat is evolved, and in the glass vessels employed it is easy to see that, with every type of apparatus except the last, steam, and even sometimes tar vapours, are evolved.

Before proceeding to discuss the chemical actions and physical effects taking place in these forms of apparatus, it will be well to see the way in which these laboratory types have been adapted in practice to the

generation of acetylene on a large scale, and for this purpose a few of the more important of the generators will be described in this chapter as types.

Class I. Those in which water is by various devices allowed to drip or flow in a thin stream on to a mass of carbide, the evolution of the gas being regulated by the stopping of the water feed.

The introduction of Acetylene into England

It was in January, 1895, that Lewes lectured at the Society of Arts upon acetylene and the development which had been taking place in America, and pointed out that not only was the mixing of acetylene with air before combustion fraught with considerable danger, but also that a certain loss of luminosity took

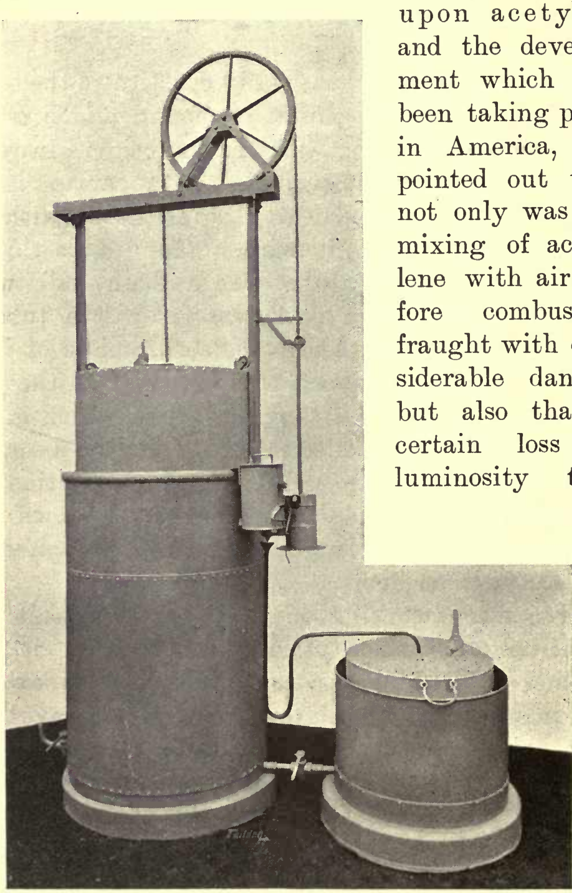


Fig. 94.

place, and showed that with exceedingly fine-holed burners of the Bray or Manchester type, acetylene could be burnt alone with wonderful effect.

The first English generator

The introduction of acetylene into England was quickly followed by the patenting of several forms of generators, the first—a patent taken by Gearing in April, 1895—being also the first automatic generator made. It consisted of an apparatus in which water was allowed to drip upon the carbide contained in a water-sealed generator, the gas being led through a condenser into a holder, the rising bell of which cut off the water when the holder was two-thirds full, whilst, as the gas was used and the holder fell, it acted upon a lever that opened a cock and started the flow of water on to the carbide once more.

Present forms of generators of the "Drip" class

This, as well as others of the earlier forms of generator, has apparently died a natural death, and at the present time the generator patented by Sir Charles Forbes may be taken as a good type of this class.

Fig. 95 shows a section of the machine, from which the working can readily be understood.

The Forbes generator

The generator A consists of a cast-iron cylinder closed at one end, and having a cover B on the other end, which is clamped up against an indiarubber packing ring C by an easily-worked fastening.

Construction and working of the generator

On the top of this cylinder is water vessel D containing an inverted gas bell E, supported on a wide pipe F, which passes up inside the inverted gas bell nearly to the top. The bell is supported in position in the tank by means of a cone G, formed on the upright pipe, which also acts as a valve for cutting off the water when re-charging; or, if it is desired, entirely stops the action of the generator. The automatic action of the generator, however, does not in any way depend upon this valve. The water has access under the lower edge of the inverted gas bell, and, on rising, reaches a small tube H, which is screwed through the

side of the upright pipe, and is bent over so that the drip of water may be discharged clear of the sides of the pipe direct into the centre of the carbide drawer J beneath.

The carbide drawer is provided with a V-shaped division in the centre, so that no carbide can be placed immediately under the drip L. The water falling in a drip or very fine stream into the bottom of the carbide drawer and spreading both ways slowly attacks the carbide M.

Arrangement of the water supply

When the generator is charged with calcium carbide, and the superposed tank filled to the desired level with water—which may be done by hand, but is more usually supplied from a controlling cistern—the water rises under the bell of each generator until it reaches the small dripping tube, and then falls into the carbide drawer in the cylinder below. The gas is generated, passes in at

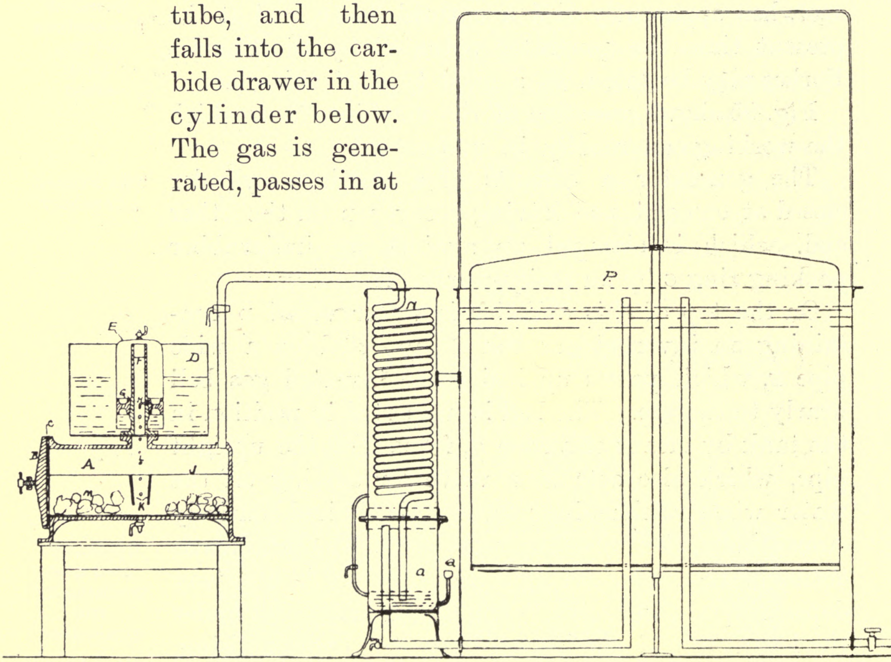


FIG. 95.

the top of the cooling coil N, which is surrounded by water, and is discharged through a small quantity of water in the washer O, thence into the

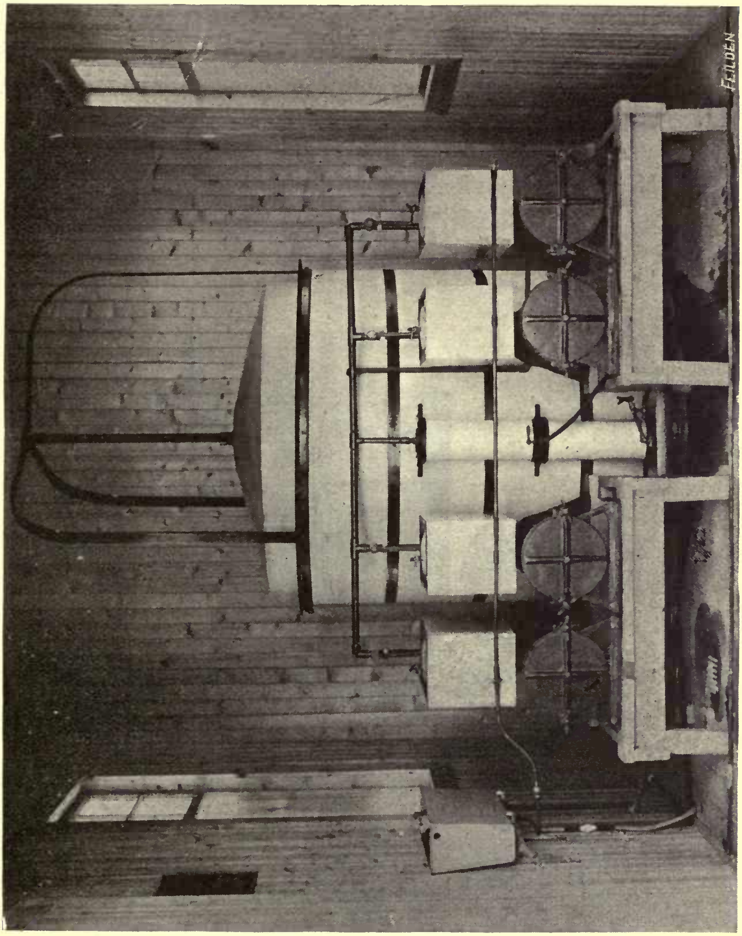


FIG. 96.

holder P. As the holder rises, its gradually increasing weight balances the head of water in the generator tank or tanks. At this point the water is automatically displaced under the small bells in the

Automatic arrangement for stopping the generation

generator tanks below the level of the small dripping tubes, when the discharge of water into the generators ceases. The generation of gas then gradually stops, and does not begin again until the holder falls to the balancing point.

Fig. 96 shows an installation of this plant on a large scale, with a battery of four generators feeding the storage holder.

"Midland" Acetylene generator

Another form of drip generator is made by the Midland Acetylene Syndicate. It consists of a dis-

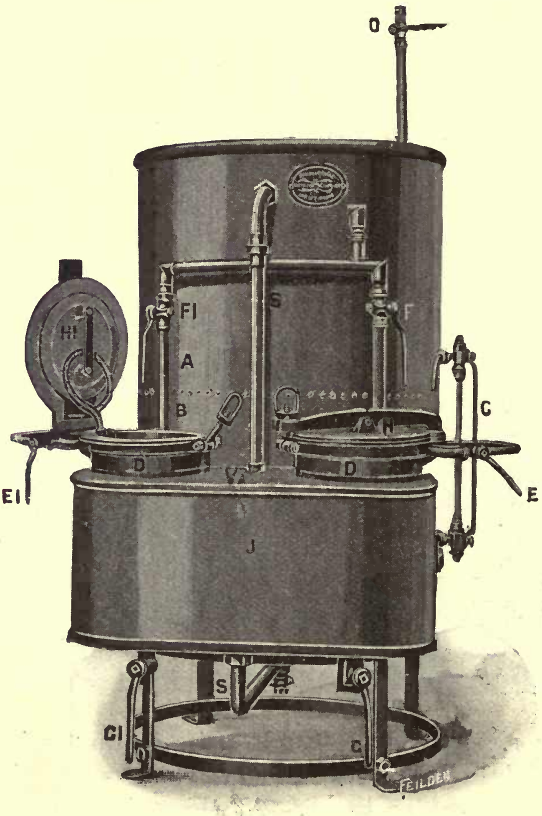


Fig. 97.

placement holder supplied by generators varying in number with the capacity of the holder, these generating chambers being arranged at different levels so as to come into action consecutively. The carbide is contained in a perforated gauze cage, and placed in the generators D, the hinged covers H and H^1 being then clamped down. These generators are set in a large water jacket J, and water drips upon the carbide from a perforated ring fitted to the hinged cover, and to which water is supplied through the inlet taps E E^1. The gas then passes through the pipes and taps F and F^1 into the holder.

The generator made under Kay's patent by the

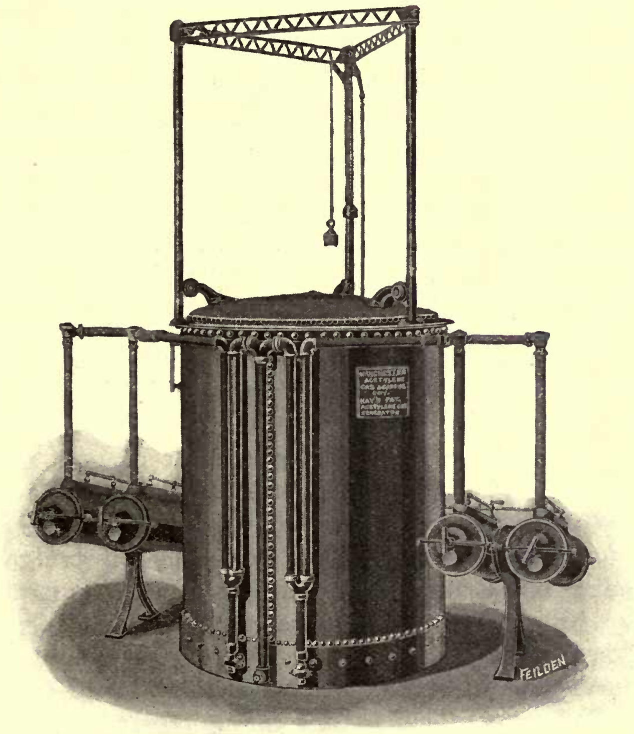


FIG. 98.

'The "Manchester" Acetylene generator

Manchester Acetylene Gas and Carbide Co. also consists of a holder with external retorts fitted in a sloping position to the sides of the holder tank. These retorts vary in number according to the capacity of the holder. The calcium carbide, broken to the required size, is placed in wire baskets, and three baskets go to form the charge for each cylinder. Along the top of each cylinder a small water supply pipe passes, having three branches through which the water drips on to the carbide in the baskets below, the water supply being regulated automatically by a valve controlled by the gas holder, the rise of which beyond a certain point lifts a small balance weight which shuts the water valve, which is again opened as the holder falls. The gas evolved in the retorts is led up by a vertical pipe, through a check valve and syphon pipe, to catch any products of condensation, after which it passes down a descending pipe and enters the receiver at the bottom.

Arrangement for automatic control

The formation of a lime coating over the Carbide in drip generators

In many forms of drip machines a certain amount of trouble is experienced owing to the formation of a thick coating of lime over the surface of undecomposed carbide, and, as the water which drips in often makes for itself channels in the mass, a good deal of the carbide in the interior of the lumps may escape decomposition until the whole chamber becomes flooded. An attempt has been made to overcome this difficulty in the "Beacon" acetylene generator, in which the carbide is placed in the cylinder R, made of stout steel-wire netting. Water is supplied automatically at A_2 as needed. This is effected by the regulator O, which is forced outwards from the holder by the bridge N coming into contact with it, and communicates motion by a bell crank, etc., to the valve P, which, when open, allows water to pass through the pipe V into the generator at W, where the water is divided into several small streams, which, passing through the wire netting of the cylinder, fall on to the carbide and generate the

The "Beacon" Acetylene generator

Construction of the apparatus

gas. The water tank is supplied with a gauge glass B_2 to show the height of the water.

Method of preventing the formation of a lime coating

On revolving the cylinder R, the lime produced by the decomposition of the carbide is mostly shaken off, leaving the carbide fairly clean. The lime accumulates in the lower part of the generator U, and when the

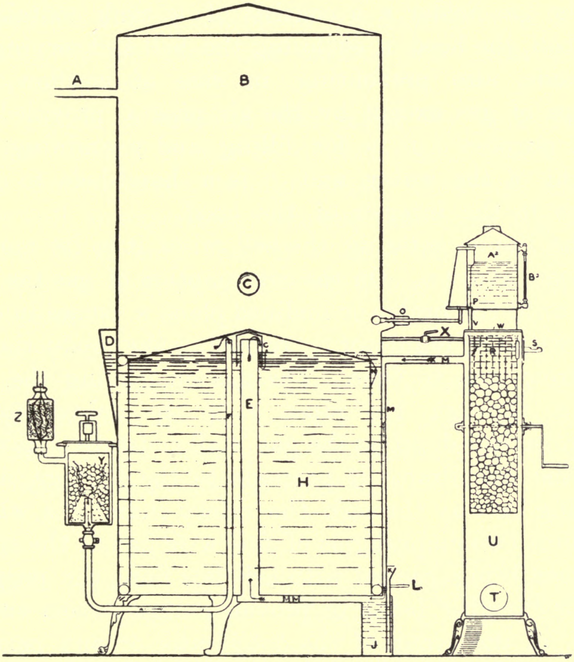


FIG. 99.

charge is spent it is removed through the gas-tight door T.

Working of the apparatus

The gas, having been liberated from the carbide, passes through the pipe M, the greater part of which is in close contact with the water in the tank H, by which means the gas is partly cooled and deprived of excess of moisture, which falls into the trap J, finding an outlet by the tubes K and L, the tube K rising

from the bottom of the trap, allowing water to flow away without danger of gas escaping. The gas, continuing its way through M M and E, which also tend to arrest any moisture contained in it, passes out of the pipe E and is forced through the water by the cap G, which forms a seal preventing the back-flow of gas when the generator is open.

Construction of the gas holder

The gas-holder B H consists of a tank containing the bell, the hood B enclosing the bell and serving as a guide, also preventing, in case of overflow, the escape of gas except by the air pipe A provided for that purpose. D is for filling and examining the height of the water, and C is a hand-hole to gain access to the interior of the hood.

The gas on entering the bell raises it to its normal position above O. On the consumption of gas the bell falls until the bridge or inclined plane N comes in contact with the regulator O, renewing the production of gas from time to time. The gas on leaving the bell passes through the pipes F to the dehydrator V, where carbide deprives the gas of all moisture. Having left the dehydrator it proceeds to the burners, after making its way through the safety chamber Z, which contains two diaphragms of fine wire gauze, the space between being packed with asbestos fibre, the purpose of the chamber being to provide security from explosions, in the event of the dehydrator or any part of the machine containing an explosive mixture of gas and air, by preventing a flame from passing back through the pipes.

Safety chamber

The pipe X is furnished for the purpose of discharging air which enters the generator at the time of refilling the cylinder. The air passes into the hood B, and thence through the pipe A to the outer air.

Desiderata in a good generator

The points to be attained in a good generator are :—

1. Low temperature of generation.

2. Complete decomposition of the carbide.
3. Maximum evolution of the gas.
4. Low pressure in every part of the apparatus.
5. Removal of all air from the apparatus before generation of the gas.

When carbide is acted upon by water, considerable heat is evolved, and to determine to what this amounted, a good sample of commercial carbide containing 92 per cent. true carbide was experimented with as follows:—

Experiments to determine heat evolved during the decomposition

A rough calorimeter was made by jacketing a beaker about 5 inches in diameter with cotton wool. This arrangement, though crude, answered its purpose well, as experiment showed that some hot water placed in it only lost ·2° C. after standing for ten minutes in a room at 18·6°C., a loss which could be neglected.

One piece of carbide, the weight of which was known, was dropped into a litre of water at a known temperature in the beaker, and the moment that the evolution of gas ceased, the temperature of the water was taken, the results being as follows:—

Experimental results

Grms. of Water.	Grms. of Carbide.	Rise in Temperature °C.	Corresponding Calories liberated.	Number of Calories liberated per Grm. of Carbide.	Time of Reaction in Seconds.
1,000	42·7	17·4	17,400	407	62
1,000	28·9	11·4	11,400	394	91
1,000	19·7	8·2	8,200	416	73

which give as an average 406 calories liberated for each gram of carbide.

Broken-up carbide, the pieces of which weighed from 1 to 5 grams, was thrown into a litre of water in the beaker in quantities of 30, 40, and 50 grams respectively.

Experiments with broken Carbide

Grams of Water taken.	Grams of Carbide taken.	Rise in Temperature ° C.	Corresponding Calories liberated.	Number of Calories liberated per Grm. of Carbide.	Time of Reaction in Seconds.
1,000	50	17·6	17,600	352	248
1,000	50	18·4	18,400	368	86
1,000	50	18·3	18,300	366	123
1,000	50	18·4	18,400	368	106
1,000	40	15·6	15,600	390	109
1,000	40	15·8	15,800	395	101
1,000	40	15·0	15,000	375	196
1,000	40	15·5	15,500	387	110
1,000	30	11·7	11,700	390	76
1,000	30	10·8	10,800	360	89
1,000	30	11·8	11,800	393	114
1,000	30	11·4	11,400	380	85

The last experiment was repeated with carbide still more finely divided, and the results gave 384 calories for each gram of carbide.

The reason of small pieces of Carbide giving less heat than large pieces

From these figures it will be seen that, contrary to expectation, the smaller the carbide the less was the yield of heat; but the reason for this is evident. More time is spent in breaking and weighing out the finer carbide than in when dealing with one large piece, and the larger surface presented by the small pieces causes greater decomposition by the moisture in the air than with the single lump, hence the carbide is of poorer quality, and, moreover, the rapid evolution of gas in the case of the small carbide prevents the water abstracting all the heat from it.

The heat evolved

Taking this into consideration, the 406 calories will most nearly represent the heat evolved by the decomposition of 1 gram of good commercial carbide, and this would be equivalent to 441·3 calories for pure carbide.

The intensity of the heat developed is

With this figure as a basis, it is evident that the action develops about one-twentieth of the heat evolved by the combustion of carbon. As, however,

the intensity of the temperature developed is a function of the time needed to complete the action, and as the decomposition of the carbide by water is extremely rapid, the degree of heat attained varies with every form of generator, and whilst the water in one form may never reach the boiling point, the carbide in another may become red hot and give a temperature of over 800° C.

dependent on the time taken in the decomposition

When water drips upon carbide, as in generators of subdivision I., the temperature rapidly rises until, after about 18 to 25 minutes, it reaches a maximum, the actual heat developed depending upon the rate of flow of the water and the way in which it is distributed over the mass; but it is quite possible with generators of this class to reach from 400 to 700° C., and it is probable that in some parts of the mass the higher limit is nearly always attained, traces of tar being generally found in the residual lime. In some cases it is in sufficient quantity to make the lime yellow and pasty, whilst vapours of benzene and other polymerisation products pass off in considerable quantities with the gas.

The development of heat in generators of the "Drip" class

There are many factors which affect the amount of heating of the mass which takes place in a "drip" generator of this class. For instance, the higher the pressure existing in the generator the greater will be the heat produced, and whereas, with an open vessel of carbide, the action may produce a temperature of only 200° C., in a closed vessel, from which no gas could escape, the carbide would be raised to a temperature of 1,000° C. and cause the detonation of the gas.

The effect of pressure on the temperature developed

Again, the temperature varies very greatly with the size of the charge of carbide and the rate at which the water flows on to it, whilst even the shape of the vessel affects the amount of heat locally developed.

The effect of the size of the Carbide charge and the shape of the generator

If a charge of, say, two pounds of carbide is spread out over the bottom of a tray, of such size that the material is in a layer of not more than 2 to 3 inches deep, the lumps of carbide not exceeding one inch in diameter, it may be decomposed by the dripping of water upon it in a fairly regular manner, and without excessive heating. But if the same charge of carbide be placed in a smaller cylinder, so that there is a depth of from 5 to 10 inches of material, then the slaked lime will form a coating on the top of the carbide column, and only allow the slow and unequal passage of the water through it, with the result that very high temperatures would be developed.

Precautions necessary in measuring the temperature generated

When experiments on this subject were made in the author's laboratory it was soon evident that special precautions must be taken in measuring the heat evolved, as in most cases the very high temperatures only occurred in certain spots; and that any attempt to detect the highest temperature existing in a mass of carbide by means of thermometers, or by strips of metal of known fusing points, was absolutely useless, as it would often happen that a thermometer in one portion of the charge would be registering a comparatively low temperature, whilst tar vapours were being developed in another portion, making it perfectly clear that there were points of local heating where the temperature was some hundreds of degrees hotter than that shown by the thermometer.

Heating often only local

A want of attention to this point has caused some observers to doubt the existence of these high temperatures in certain forms of generators; but it is perfectly clear that in those cases where benzene and tar vapours are produced, the necessary temperature for their production must have existed, and the fact that a piece of tin or lead placed in the charge was not melted merely shows that the high temperature was not evenly distributed over the whole mass.

Leaving the question of the temperature developed in this class of generator, another important point is the length of time over which generation of gas continues after the addition of water to the carbide has ceased. Makers of automatic apparatus of this type seem to think that in order to stop the evolution of acetylene, all they have to do is to cut off the supply of water. This would act very well if the generation of gas really ceased then, but this is not the case, as the gas continues to be evolved, although with increasing slowness, for a considerable period after the cutting off of the water. The length of time over which this after-generation extends depends upon the amount of water added, the amount of carbide undecomposed, and the temperature of the carbide at the time when the water supply is stopped, whilst the generation will itself depend upon—

"After-generation" in generators of the "Drip" class

Conditions governing the length of time during which "after-generation" proceeds

(*a*) The dehydration of the calcium hydrate first formed.

(*b*) The decomposition of water condensed from the gas present as the temperature of the generator falls.

The causes of "after-generation"

As we have before seen, the first result of the action of water upon the carbide is the formation of quicklime and the evolution of acetylene, whilst, if sufficient water be present, the lime takes up another molecule of water to form calcium hydrate. This molecule of water, however, at temperatures of 420 to 430° C. is driven off from the calcium hydrate, and the affinity of the carbide for any water present causes the reaction—

$$CaC_2 + Ca(HO)_2 = 2CaO + C_2H_2$$

A series of experiments was made by placing a known weight of carbide in a generating cylinder, running in a known weight of water in a given time, and carefully measuring the volume of gas for the first ten minutes, and again when the action had

Experiments on "after-generation"

practically ceased, and not more than 1 c.c. of gas was evolved in 10 minutes.

TABLE.

Weight of Carbide in Grms.	Weight of Water in Grms.	Time taken to flow in in Minutes.	Gas c.c. in 10 Minutes.	Time to complete evolution.	Volume of Gas at end of evolution.	Percentage of Carbide not decomposed.
18	9·0	4	2,400	80	2,900	50·0
18	9·0	6	2,300	90	2,800	51·5
18	9·0	8	2,400	70	2,700	53·4
18	13·5	4	2,900	60	3,300	43·0
18	13·5	6	3,000	55	3,500	39·7
18	13·5	8	3,300	65	3,600	37·9
18	18·0	4	3,700	60	4,100	29·3
18	18·0	6	3,600	62	4,200	27·6
18	18·0	8	3,700	65	4,200	27·6
36	18·0	4	4,600	88	4,300	54·3
36	18·0	6	4,650	81	4,350	53·2
36	18·0	8	4,400	57	5,500	52·0
36	27·0	4	5,600	130	6,600	43·1
36	27·0	6	6,000	72	6,650	42·7
36	27·0	8	5,850	61	6,850	41·0
36	36·0	4	7,000	60	7,850	32·2
36	36·0	6	7,100	54	8,400	27·6
36	36·0	8	7,400	49	8,500	26·7
54	27·0	4	5,900	105	6,600	62·1
54	27·0	6	5,800	78	6,300	63·3
54	27·0	8	5,800	85	6,400	62·6
54	36·0	4	6,000	102	6,950	60·0
54	36·0	6	6,300	79	7,500	56·9
54	36·0	8	7,000	109	8,900	48·8
54	54·0	4	6,600	90	8,800	49·4
54	54·0	6	7,700	103	8,900	48·8
54	54·0	8	7,600	105	10,400	40·0

Experimental results

The results so obtained showed clearly that in any apparatus on this principle the cut-off should be so arranged that at least one-fourth of the total holder capacity is still available to store the slowly generated gas.

Volume of water required to ensure complete decomposition

An important point was noticed in these experiments, viz. the large excess of water required to ensure complete decomposition of the carbide, over and above the theoretical quantity. The excess of water

needed was largely dependent upon the form of generator employed.

According to theory, 64 parts by weight of carbide require only 36 parts by weight of water to completely decompose them and convert the lime into calcic hydrate.

Causes necessitating a large excess of water

This would mean that each pound of carbide needs a little under half a pint of water to complete the action, whilst in practice, owing to the evaporation due to the heat of the action, half the added water is driven off as steam with the acetylene, or left mechanically adhering to the lime, and the smallest quantity likely to complete the action would be a pint to a pound of carbide, whilst in reality the only safe way is to add sufficient water to drown the residue.

Danger of undecomposed Carbide in the residue

If this is not done the lime forms so protective a coating to the carbide, that small quantities often remain undecomposed, and if the residues are thrown into a drain or cesspool the evolution of acetylene would give an explosive mixture, which, on account of its low point of ignition, would be a serious danger.

The "Drip" generator practically abandoned on the Continent

These troubles have had a serious effect upon the future of this class of generator on the Continent. In the early days of acetylene lighting, the "drip" generator was a favoured type with the manufacturers of acetylene apparatus, but the troubles of overheating, after-generation, and often incomplete decomposition of the carbide, have led practically to their abandonment, so that at the present time very few of this class are to be found outside England and America.

Second subdivision of generators

The second subdivision of generators, in which water rises to the carbide, is very popular, and overheating can be avoided in these, provided they are so arranged that the water is never driven back from the carbide; and if the charge of carbide used is not too great. Under these conditions, the slowly rising

water is always in excess at the point where it decomposes the carbide, so that the evaporation, by rendering heat latent, keeps down the temperature, and although the steam so formed partly decomposes the carbide in the upper portion of the charge, the action is never sufficiently rapid to give any very great rise of temperature. In order to fulfil these conditions, it is necessary that there should be a holder of considerable capacity, and that the leading tube, conducting the gas from the generator to the holder, should be of sufficient diameter to freely conduct away the gas, the water being allowed at the same time to rise in the generator so slowly as to do away with any risk of over-generation.

Water rising to Carbide

Conditions neccssary in a good generator of the second class

In the best generators of this class, these conditions are more or less approached, and it is unusual to find that the melting-point of tin, 228° C., has been reached in the charge of carbide during decomposition.

Automatic generators of the second class

Where apparatus of this class are automatic, and have no rising holder to take the gas, it is found that they work satisfactorily when supplying the number of lights for which they were designed, but if they are over driven, and the action becomes too violent, excessive heating takes place, whilst the turning off of the gas and consequent driving back of the water from the carbide also has a tendency to raise the temperature. If, however, the water has risen sufficiently slowly, the carbide below the surface has been practically all decomposed, so that the heating only takes place over a limited zone.

Conditions existing in these generators

Early type of American generator

The first generator put upon the market in America consisted of a glazed earthenware "crock" with two tubulures at the side, and a lid that clamped gas-tight on to a wide mouth at the top. The carbide was placed in a perforated zinc cage inside the "crock," and, standing on a small stool, water was admitted by one of the side tubulures, and, collecting

at the bottom of the vessel, gradually rose until it came in contact with the carbide, the gas escaping by the second tubulure to the holder. The gas was then mixed with an equal volume of air in a mixing meter, and passed on to the burners. (Fig. 100.)

The "Ideal" Acetylene generator

The natural development of this early generator is to be found in the "Ideal," in which a strong metal cylinder with conical bottom, closed by a screw-down lid, and fitted with a sludge cock for the removal of the spent lime, contains the wire carbide cage. At the side of this chamber is the water entrance pipe fitted to a supply cistern, the level of which is so arranged that it is impossible for the water to more than flood the carbide.

Arrangement of water-feed

The whole of the apparatus is so regulated that the liquid only slowly rises in contact with the

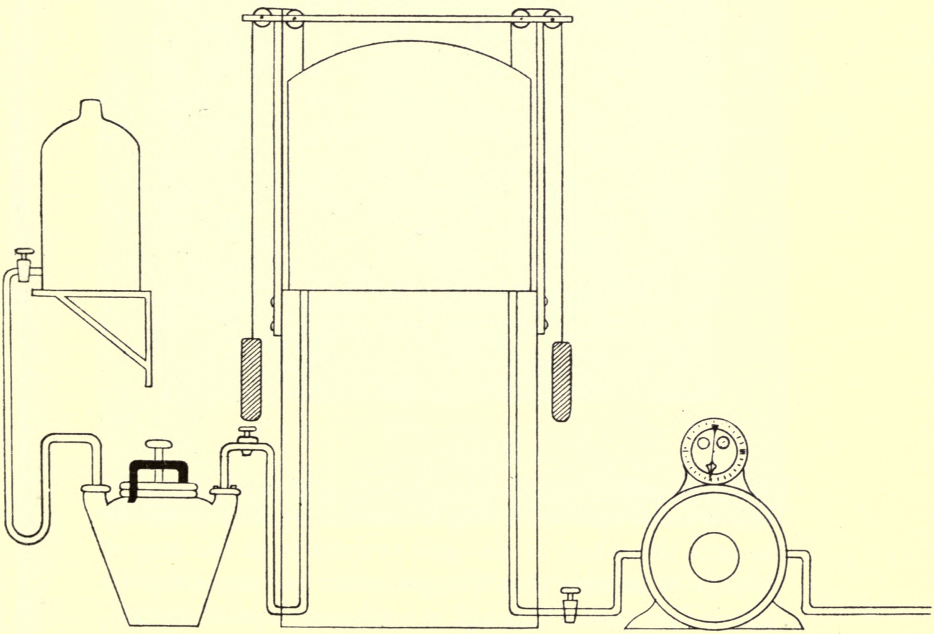


Fig. 100.

carbide; and should there be any excess of gas, due to over-generation, it stops the inflow of water into the generator till the pressure again falls, when more enters.

The apparatus, Fig. 101, is extremely simple and

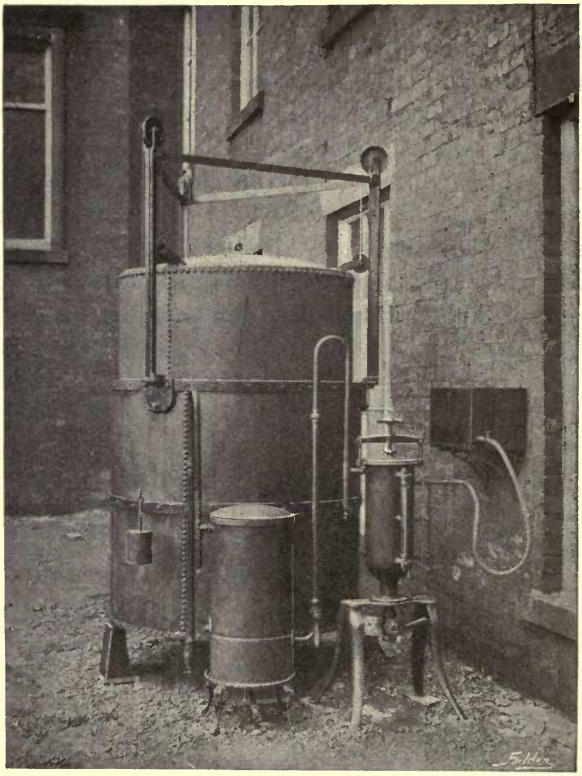


FIG. 101.

works admirably, the gas as it is produced being led into a small holder, having a sufficiently large capacity to take the whole of the gas evolved from the largest charge of carbide that the generator can contain; the gas is first passed through a condenser, and, if desired, a purifier, and stored in the holder for use.

When the charge is thoroughly spent, the water has risen to the top of the generator, and the residues being entirely flooded there is no danger of any

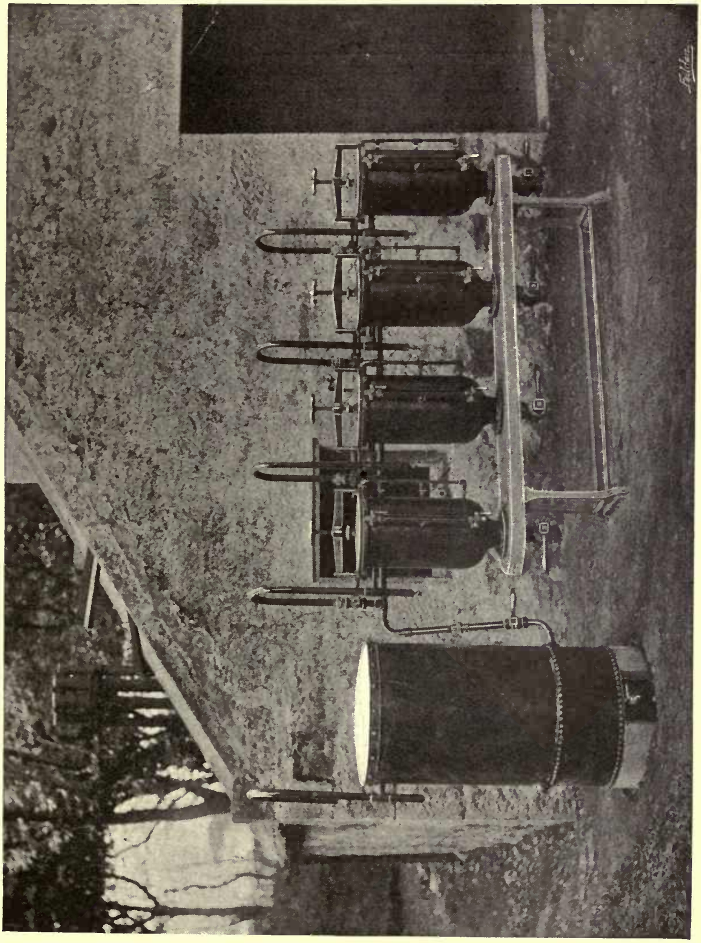


FIG. 102.

undecomposed carbide being thrown away with the lime sludge.

In order to avoid the evolution of an excessive

Subdivision of the charge of Carbide in large installations

temperature during generation, it is important that the charge of carbide should be kept small, and in fitting up large installations this is attained by increasing the number of generators instead of increasing them in size, and the accompanying illustration, Fig. 103, shows such a battery, arranged to supply gas to a large store gasholder.

The "Sunlight" generator

Another generator of the same class, also non-automatic, is the "Sunlight," in which a novelty

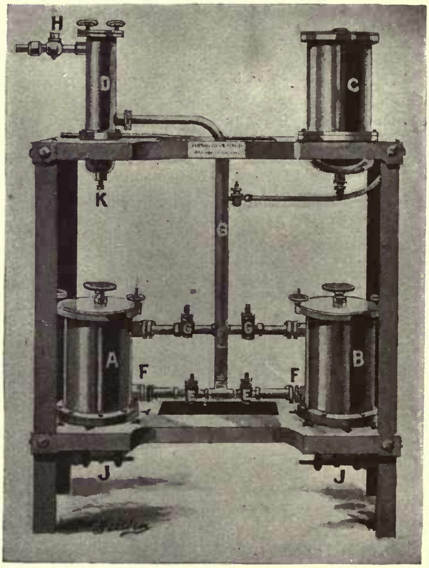


FIG. 103.

is introduced, in as much as acetylene mixed with carbon dioxide is produced, instead of the pure gas, it having been shown that the diluted acetylene is more easily consumed, without risk of smoking at the burner, than the pure gas.

The Acetylene diluted with a small

In order to do this, the generators A and B, Fig. 103, are made of iron, lined with lead, and contain perforated iron baskets, in which is placed a small proportion

of any form of calcic carbonate—whiting being generally employed—whilst on the top of this the charge of carbide is placed. A cylinder C, also lined with lead, is fixed at a higher level, and contains a five per cent. solution of sulphuric acid, which flows down a pipe and enters the generating cylinders at a point F, close to their base. As it rises, the dilute acid comes in contact with the calcic carbonate, evolving carbon dioxide; whilst, on reaching the carbide, acetylene is also produced. The mixed gases, on leaving the generator, then pass through the exits at G, and travel upwards to a cylinder, D, which contains the purifying material employed, consisting of an acidified copper salt, which removes the sulphuretted and phosphuretted hydrogen, the purified gas then going forward to the gasholder.

quantity of Carbon Dioxide

Purification of the gas

It has been proved that a small amount of carbon dioxide has but little effect on the illuminating power, and has a distinct action in doing away with the danger of smoking.

Action of the Carbon Dioxide

A popular form of generator is made by Exley, Fig. 104, in which the generating chambers consist of vertical iron retorts, placed round a cylindrical iron vessel, the lower portion of which is a water tank and gasholder, whilst the upper portion contains a condensing coil, and also acts as an overflow when the water is driven back from the lower tank by excessive generation of gas. The generators, which vary in number according to the capacity of the plant, contain cages into which the carbide is placed, a screw-down cover making the whole gas-tight. Water is admitted from the central tank to the bottom of the generator, and rises until it reaches the carbide. The gas which is then evolved is led from the generator into the upper portion of the water tank, and, collecting there, drives the excess of water into the upper tank, and as soon as the pressure

The Exley generator

Construction of the generator

reaches a certain point, the pressure of gas drives back the water from the carbide. The water again falling from the overflow tank as the gas is consumed, rises to the carbide once more, so that the supply of water to the carbide is automatically regulated by the pressure of gas within the gas-holder. As soon as the decomposition is complete in one generator, and the water has risen to the top, it flows over into the second generator, and this action continues until the whole battery has been exhausted.

Automatic regulation of the water supply

Exley generator used with storage holder

In some cases, where it is imperative to have a gas-holder, the apparatus is connected directly with it, and the gas being then made steadily, until the holder is full, variations in pressure are done away with.

Read-Holliday Acetylene generator

An acetylene apparatus of almost identical construction is the one made by the Read-Holliday Acetylene Co., who were amongst the earliest makers of generators in this country.

Construction and working of the Read-Holliday generator

It consists of a generator A, Fig. 105, which contains a cage, holding the carbide in connection with a displacement holder. Water is admitted to the generating vessel by opening the cock H, when water rising in A, and coming in contact with the carbide, generates the acetylene, which passes through a coil of pipe in the water cistern C, so that any excess of moisture brought over with the gas is condensed, and runs back into the generator, whilst the acetylene passes on to the service pipes. Should any excess of pressure arise, owing to over-generation, it forces the water away from the carbide and drives it back into the lower holder B; the excess of gas also passing through the same tube, and, collecting in B, drives the water up the central tube into the coil cistern C.

In this way, the tank B acts as a displacement holder, the pressure in which increases with the depth of water driven up into the cistern C, and, as soon

as the consumption of gas again exceeds the generation, the acetylene stored in the displacement holder passes through the generator to the outlet, being

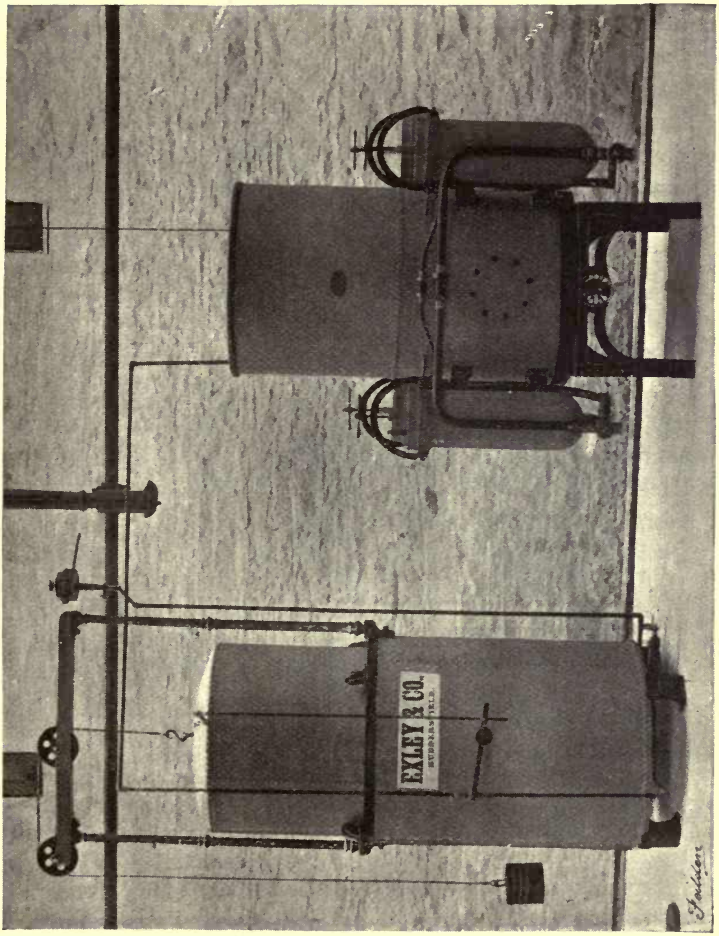


Fig. 104.

followed in turn by the water, which, on reaching the carbide again, gives rise to the evolution of a fresh supply of gas. This form of apparatus can

of course have the generators multiplied to the required gas consumption, and is, in fact, made to supply installations of from 10 to 1,000 burners. In a large installation it is as well to use the machine in conjunction with an ordinary gasholder, but in many cases it is preferred to use a battery of the large size displacement holders, with their attached generators, Fig. 107 showing an installation of this character.

Battery of generators

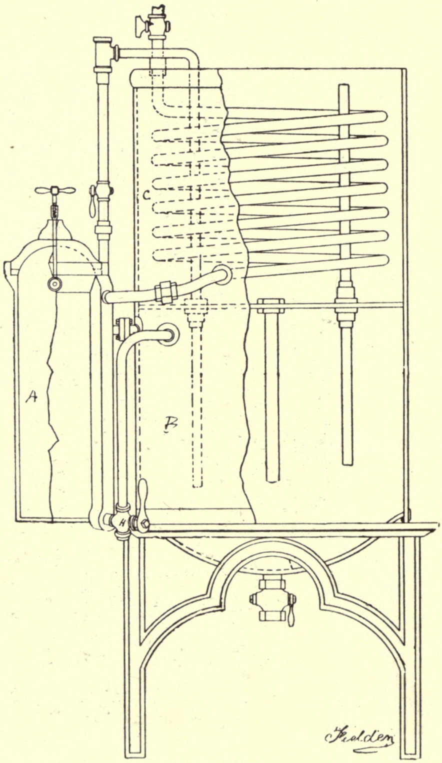


Fig. 105.

"Thorscar" generator

The "Thorscar" generator, as it is termed, differs only from the "Exley" and "Read-Holliday" apparatus in detail, and, like them, consists of a vertical generator, in which the carbide is placed in a cage subdivided into several compartments, in which the water rises from below, and the gas then passes into a tank fitted with a rising gasholder instead of a displacement holder, as in the two previous forms of apparatus. Fig. 108 gives a section of the apparatus.

Construction

The action of the machine is extremely simple.

The holder is charged with water so that when it is resting on the bottom the water is above the level of the supply pipe leading to the lower part of the generator, and under these conditions the water flows down the pipe, rising to the carbide, and evolves the

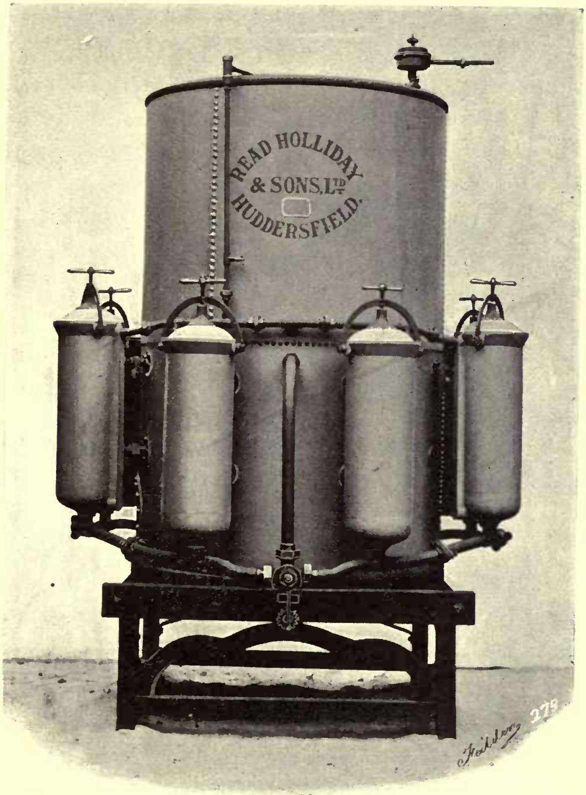


FIG. 106.

gas, which is led off by the outlet pipe to a small water dip-chamber, which, although it allows the gas to pass freely from the generator, prevents any return taking place, this water-lock or seal being a distinct advantage. Leaving the seal, the gas flows on into

the holder, which, rising, causes the water to fall below the level of the supply pipe, so that after a time the generation of gas ceases. As the gas is drawn off for

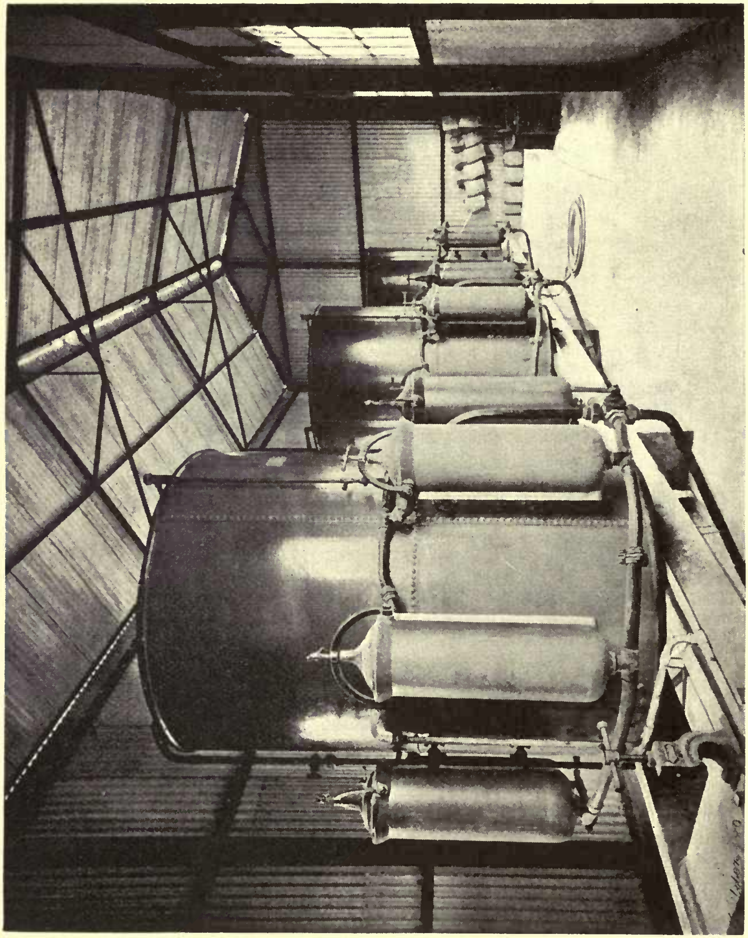


Fig. 107.

Water supply

consumption the holder again falls, and, having a displacement cone inside it, causes water to again rise to a sufficient level to flow into the carbide, this operation

continuing automatically until the whole of the carbide in the trays is exhausted.

Subdivision of the Carbide charge

The subdivision of the carbide cage into several compartments, and the fact that a considerable surface of water is present at the point where the carbide is undergoing decomposition, tends to prevent overheating, and in the latest forms of apparatus the size of the holder is so arranged as to be capable of containing the full volume of gas made from the charge of carbide used.

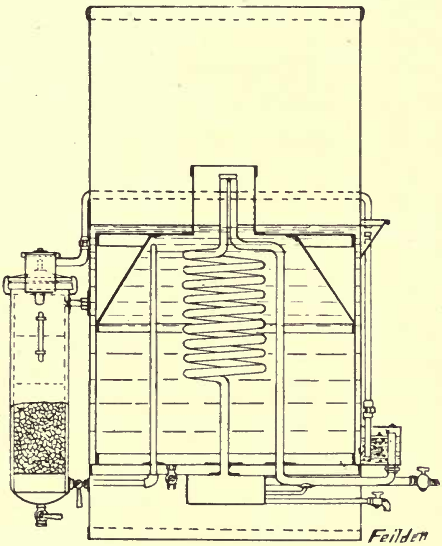


Fig. 108.

This, of course, somewhat increases the size of the holder, but on the other hand does away with the risk of overheating which exists when the pressures during generation are at all high.

Scrubber and condenser

The gas passes through a small purifying box, containing charcoal, which acts as a scrubber, and removes condensation products from it, and the gas is also to a considerable extent washed in the water-seal and in the holder. As the gas leaves the holder it is passed through a long coil of pipe contained in the water of the generator tank, any condensed liquids being collected in a catch-box at the bottom of the apparatus, whilst the gas passes on to the purifiers in which the traces of phosphuretted and sulphuretted hydrogen are got rid of.

Bailey's generator

Another acetylene apparatus, closely allied to the Exley and Read-Holliday forms, is that made by Messrs. W. Bailey & Co., which consists of vertical

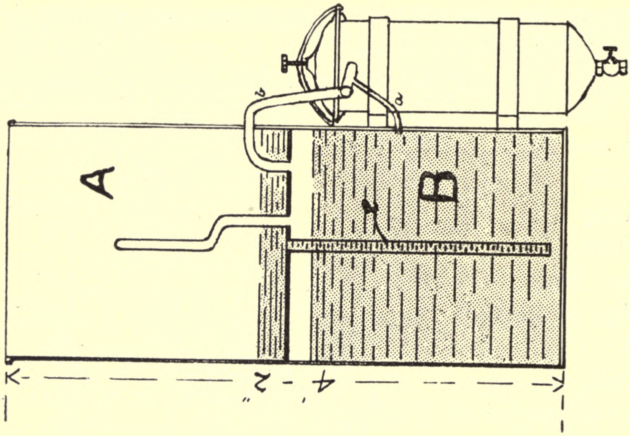


FIG. 110.

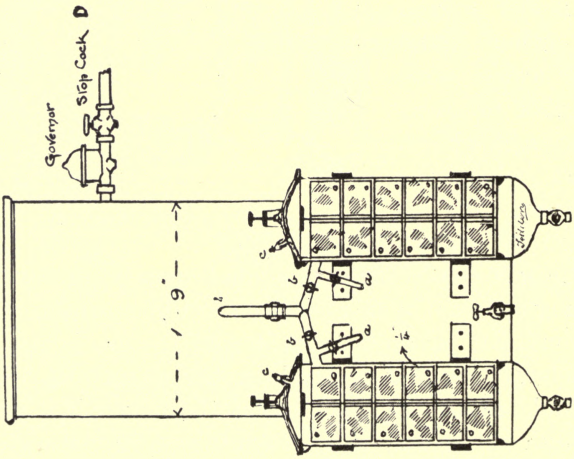


FIG. 109.

exterior generators containing the carbide, and a double compartment displacement holder, in which the acetylene is collected, and drives the water from the lower to the upper tank compartment, the pres-

sure varying with the head of water driven into the upper tank. The generators with the particular arrangement of tubes adopted are shown in Fig. 109, whilst a section is shown in Fig. 110.

Construction and working

In using this apparatus, the outlet cock D, Fig. 109, is opened, and the upper cistern A being filled with water, it flows by gravity into the gas receiver B. As soon as this is full, and a depth of a few inches of water remains in cistern A, the stop-cock D is closed and the gas cocks *b b* leading to both generators are opened, and also the water cock *a* to one generator. The water flows in, the acetylene commences to generate, and escaping by the pipe *b* into the displacement holder drives the water from it up into the reservoir A. This continues until the water has been driven below the water inlet of the generator. As the gas is withdrawn, the water again descends from the tank to take its place, and, rising above the level of the water inlet pipe of the generator, again produces more gas. This goes on until the charge of carbide in one generator is used, and the water level has risen to the top, when the water flows over, through the gas outlet pipe, into the second generator, and there starts a similar action.

Drawbacks of a displacement holder

All forms of displacement holder have the great drawback, that, as the water is driven from the lower to the upper tank, the pressure increases to a very considerable extent, and, as in most of them the water is also driven back from the carbide at the same time, the conditions become highly favourable for overheating, this being undoubtedly the great difficulty in generators of this type.

Advantage of a store holder

Besides the trouble arising in such generators from the variation in pressure, it also necessitates the use of a governor on the service pipes, and as these contrivances are none too reliable over a considerable range of pressure, the providing of a store holder,

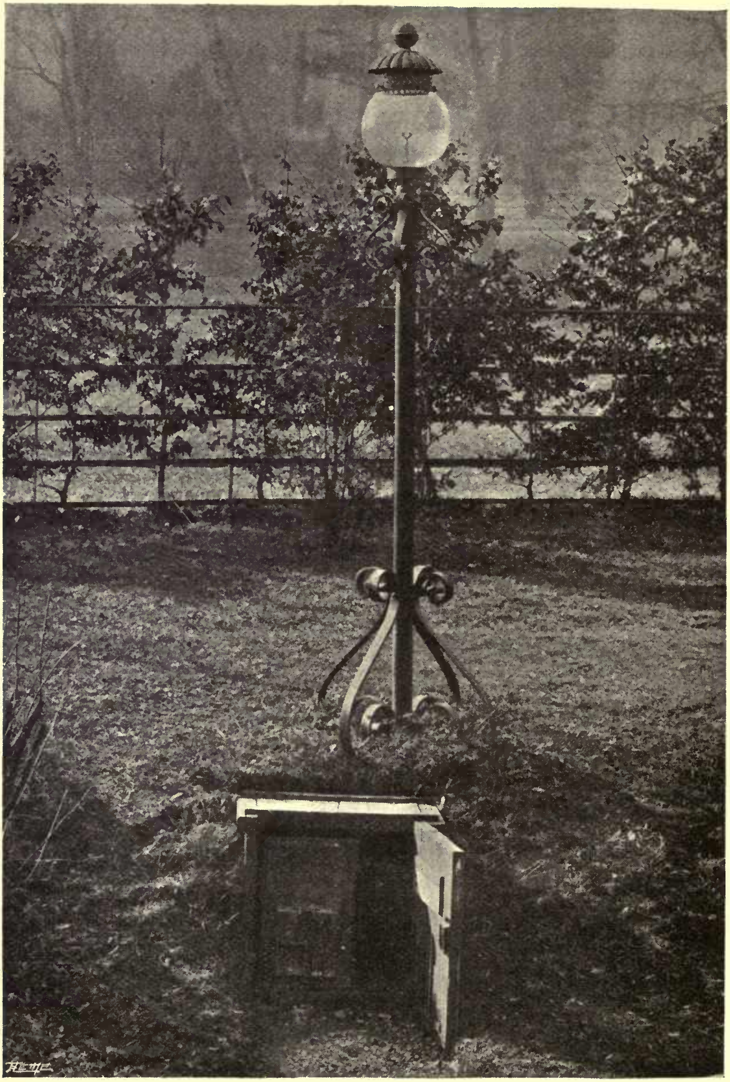


Fig. 111.

which keeps the pressure constant, is a distinct advantage.

Sir H. Grubb's generator

In order to obviate the changes in pressure due to a displacement holder, Sir Howard Grubb, of optical fame, devised a generator in which the cistern for

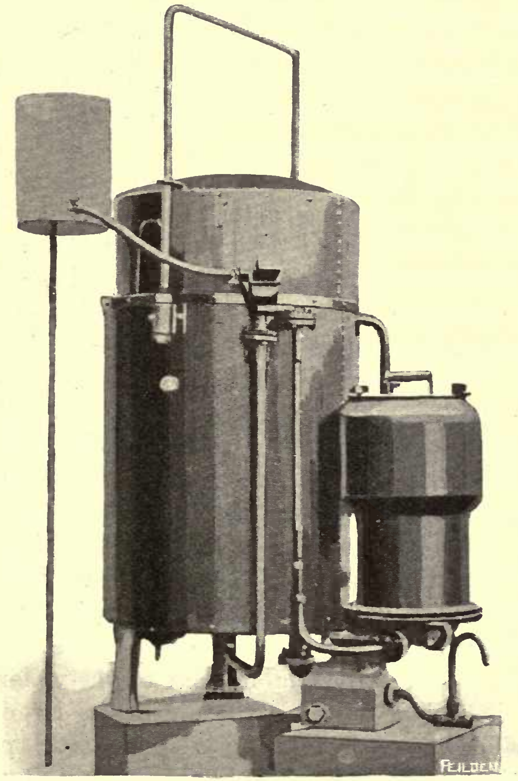


Fig. 112.

supplying the water to the carbide chambers was suspended from four long spiral springs, so proportioned that for each inch of water that flows out the lightening in weight causes the spring to raise the cistern two inches, so keeping the difference in height between

the water in the supply cistern and that in the receiver constant.

Hutton Generator

Yet another vertical generator of this type, with automatic action, is to be found in the generator made by Hutton & Co., of Galashiels, in which the generation of gas drives the water away from the carbide. The firm also makes small generators of the same kind for drive lamps (Fig. 111), which answer very well in cases where the lamp is so far from the house supply as to render its connection with the main installation too expensive.

The Fourchotte generator

Amongst the automatic generators constructed on the principle of allowing water to rise in contact with the calcium carbide, that designed by Professor Fourchotte shows several distinctive features. In its usual form it consists of a small holder with external generator or generators attached. These only differ from the usual form in that they have the upper portion water-jacketed, and the charge of carbide as far as possible sub-divided, to prevent overheating.

General construction

Arrangement of water supply

The water rises from below, and floods the carbide compartments successively, the flow of water being regulated by a broad tube, fitted gas-tight to the underside of the top of the holder, and which covers the water supply pipe F, Fig. 113. This is kept filled with water to the level of the water in the tank by means of a hole drilled in it close to the water line, and as the holder descends the air in the large tube becomes compressed, forming a pneumatic piston, which drives the water in the supply pipe up to a return valve D, and then down to the bottom of the generator. The carbide trays A are taken out for recharging by removing the lid of the generator, and arrangements are provided for maintaining a constant water level in the holder tank and the removal of any excess of water from the generator. In this form of the apparatus the pneumatic regulator of the water

supply was in the centre of the holder, and any stoppage or trouble with it necessitated dismantling the entire holder, and to obviate this possible trouble a modification of the arrangement has been introduced, by which the pneumatic piston is made external to the holder.

A very good installation of this plant is to be seen at Wolverton Station on the Great Eastern Railway, which is lighted throughout by acetylene, as is also the station approach. **Installation of the Fourchotte on a large scale**

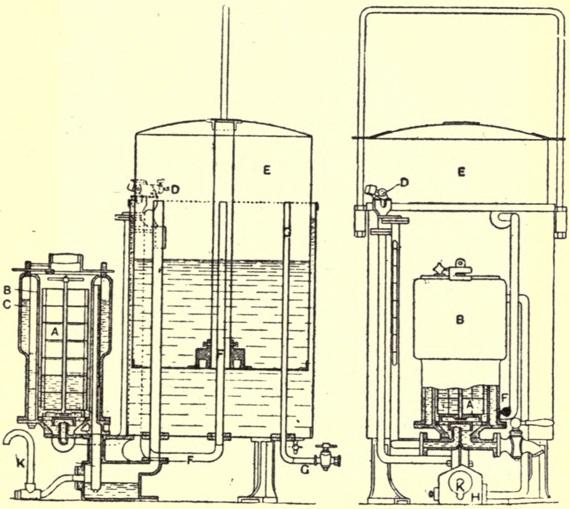


Fig. 113.

Fig. 114 shows the generator building, whilst Fig 115 shows the two generating machines which supply the acetylene to the whole installation.

In some forms of generators belonging to this class, in which water rises until it comes in contact with the charge of carbide, the principle is adopted of fixing the charge in the upper portion of a metal bell, and lowering this into a tank of water. The air within the bell prevents the water rising in contact with the carbide **Modification of this form of generator**

until the tap connecting the upper portion of the bell with the holder is opened: when the water rises, reaches the carbide, and gas generates and passes forward to the holder. Should over-generation take place, or the top of the outlet of the generator be closed, then the pressure of gas drives the water down in the bell, and generation slackens.

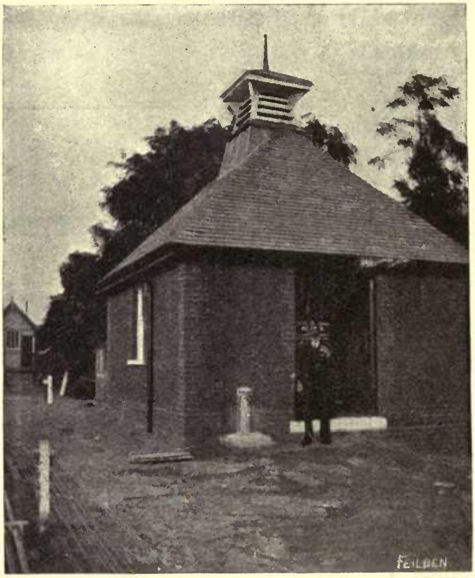


Fig. 114.

The Trouve generator

One of the earliest generators made on this principle, and which gave very good results, was the Trouve apparatus. The usual form consisted of a gasholder, to the inlet of which was attached a T-piece, connected to the outlets of two bells, standing in separate cylinders of water. The carbide cages are fixed either on stands or tripods within the bells, or by springs in the bells, their position being such that when the bell is placed in the cylinder of water, they shall be an inch or more above its surface.

Construction

This form of apparatus worked extremely well as long as the charges of carbide were kept of reasonable size, and the generator enjoyed considerable popularity in France. The drawback to it was, that indiarubber or other flexible tubes had to be employed to connect the generator to the holder.

Flooding forms of apparatus

The importance of sub-dividing the charge of carbide employed in the generator, in order to reduce as far as possible the risk of excessive heating, led to the intro-

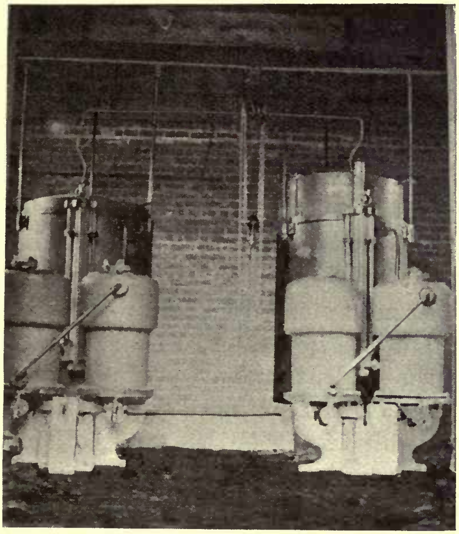


Fig. 115.

duction of a type of generator in which the rise of the water successively floods vessels containing the carbide arranged at such heights or levels that the decomposition in one is completed before the water reaches the next. The Graetz generator may be taken as a type of this form of apparatus, which undoubtedly has the advantage that it largely does away with the trouble of after-generation, as only one vessel being attacked at a time, and then completely flooded, and all the gas

The Graetz generator

the carbide is capable of giving off generated, stopping the rise of the water does to a great extent stop the evolution of gas.

Construction and working

In this generator a series of carbide cylinders with perforated lids, are placed upon a gradually-ascending spiral stand in the interior of the generator. Water is supplied to the generator by an automatically controlled valve in connection with the supply cistern, and the water rises until it floods the lowest of the cylinders. With the rise of the holder, and consequent slight increase of pressure, the valve closes the water supply tap; and, as the holder falls, the water is again fed into the generator and liberates gas from the second carbide holder, the action continuing until the water has risen above the level of the highest cylinder, when the generator has to be recharged.

Owen's generator

Several other very good forms of this type of generator are to be found on the Continent, whilst the arrangement most generally adopted in England is well shown in Owen's generator, Fig. 116, in which the falling of the holder opens a water valve and supplies water to the carbide contained in the sloping retorts fixed to the side of the holder tank. The carbide, as in the other cases, is placed in a tray divided into compartments, which slips easily into the retort; and, the water being admitted at the top, the first compartment fills, and when the whole of the carbide is decomposed the water overflows, owing to the angle at which the retort is placed, into the second division, and this continues until the whole of the charge is decomposed.

Construction

The gas outlet from the generator is taken from a small dome or box, which prevents the swelling of the lime formed during the decomposition from choking the outlet.

This form is hardly so good as the one before described, as, the carbide trays being open, the carbide

in the lower ones is sure to be acted upon to a certain extent by the condensation of moisture as the gas cools down; whilst, with the special lids used in the Graetz generator, this hardly takes place at all, some carbide removed from one of the top cylinders and

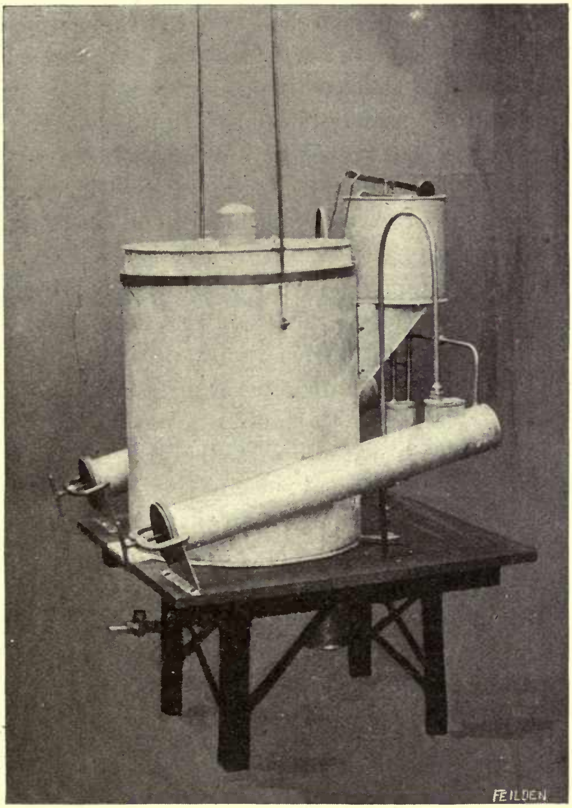


FIG. 116.

tested by the author yielding 3·5 c. ft. per lb. (220 litres per kilo.), after standing with water in the generator for four months.

Dr. N. Caro,[1] in detailing experiments made with

[1] *Zeit f. Beleuchtungswesen*, 1898, 10, 34.

Caro on the flooding type of generator

this type of generator, points out that "the carbide in each small receptacle is flooded by a relatively large quantity of water, and the whole of it is decomposed at once. The evolution of gas takes place rapidly and in sudden rushes, therefore it is absolutely necessary to use a gasholder in order to avoid dangerous increases of pressure in the generators. An excessive rise of temperature can only occur momentarily, as the carbide is surrounded by an excess of water, which effectually diminishes the heat develcped by the reaction. When the carbide receptacles are disposed side by side, however, the water flows from one into the next before the decomposition of the carbide in the first is completed, and the overflow at first is small. Thus the conditions resemble those existing in generators of the first class. Caro has indeed observed a rise in temperature of 210° C. (410° F.) in a horizontal generator of this class. The generators where the carbide receptacles are placed one above another are undoubtedly preferable to those in which they are ranged side by side.

Heat evolved

After-generation in flooding generators

"Both types have one fault in common, viz. the after-evolution of gas. The after-evolution does not arise through the reaction of carbide on calcic hydrate, but is due to the action of aqueous vapour on the carbide. The heat of the reaction drives off aqueous vapour, which acts on the carbide in adjacent receptacles. When carbide was stored in a generator over the surface of water for 8 days it lost 30 per cent. of its gas-making value; but when carbide was decomposed in a lower receptacle, that in the upper receptacle lost 40 per cent. of its value. A greater amount of carbide appears to be decomposed by aqueous vapour in horizontal than in vertical generators of this class, probably because the temperature is higher and the evolution of aqueous vapour greater in the horizontal generators. Caro

Amount of "after-generation"

concludes that the use of a generator of this type is quite reasonable, but a gasholder capable of receiving 40 per cent. of the gas which the carbide in the

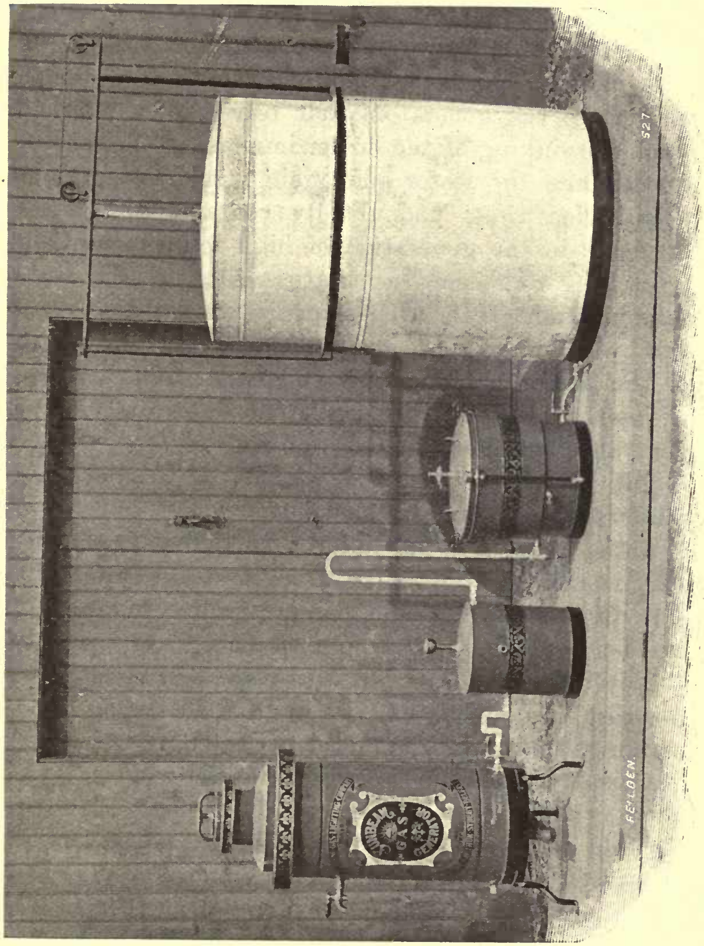


Fig. 117.

generator would yield must be used in conjunction with it. In the generators in which the receptacles are side by side, the water should flood the carbide

in each receptacle at once, instead of flowing in slowly, as is the case with most of the existing generators of this type."

The third or "dipping" class of generators

As has been before stated, subdivision of the charge of carbide and slow rise or supply of water to the carbide prevent any serious rise of temperature in this class of generator, but the third division, in which are the generators that rely for their action upon the sinking of the holder immersing the carbide carrier into the water and again withdrawing it as the holder rises, undoubtedly contains the worst offenders in the generation of high temperatures.

The Sunbeam generator

In the "Sunbeam" apparatus, Fig. 117, the automatic action of the generator is wisely not relied upon to do more than govern the rate of feed of gas to the holder, which is of sufficient size to contain the gas made from the largest charge of carbide the generator will contain.

The complete apparatus consists of a generator, condenser, purifier, and gasholder.

Construction of generator

The generator is in reality a small holder B (Fig. 118), working in the tank A, a water-sealed cylinder C, carrying the carbide cage, being fixed in the crown of the holder. The carbide in its holder is attached to the cylinder, which is put into place and is rendered gas-tight by means of the water seal, which is so arranged that by the time the carbide cage is lowered sufficiently to reach the water in the holder tank, there is a seal of six inches of water to prevent escape. As soon as the carbide touches the water acetylene is generated, and if the gas comes off more rapidly than it can pass through the condenser and purifier to the main holder, it accumulates in the generator holder, which, on rising, withdraws the carbide from contact with the water, and slows down the generation; and when the generator holder again descends it once more plunges the carbide into the water and causes

further evolution of the gas, this action continuing until the carbide is exhausted. The generator is fitted with a sludge cock G and a draw-off cock F^2

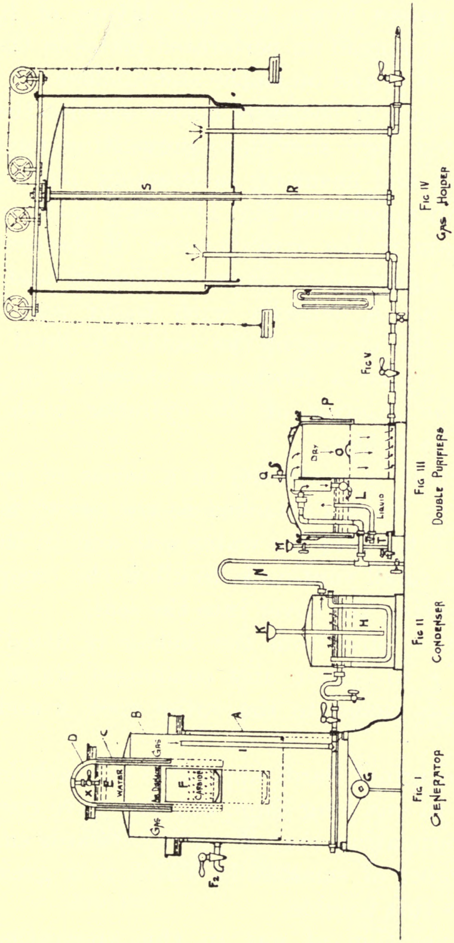


Fig. 118.

to regulate the height of water in the generator tank.

Washing and purification of the gas

The gas is led from the generator through a condenser, where it is washed to free it from ammonia, and is then led through the purifier, which is divided

vertically into two compartments L, O, in the first of which the gas is made to pass in thin streams through a layer of 1·5 inches of refined petroleum, which washes it free from benzene and tar vapours, and the gas then passes down through layers of lime and oxide of iron, spread on perforated plates in the second compartment O, and on to the store holder.

The presence of the store holder enables the gas to be generated very slowly, so preventing any serious overheating and ensuring satisfactory purification.

The Sardi generator

The Sardi apparatus, Fig. 119, very much resembles the Sunbeam in the arrangement of generator. It consists of a gasholder C, counterbalanced and floating in a tank D. A cylinder with water seal B passes down from the crown of the holder to level with its lower rim, whilst a short arm, closed by the cock H, connects the interior of the cylinder with the gas space in the holder.

Arrangement of Carbide cells

The carbide is contained in a series of perforated zinc cells or trays A attached to the rod A^1, fixed to a cover which fits into the water seal, and in the top of which is a small vent-cock, to allow the escape of air whilst lowering the cover into the seal.

The outlet pipe from the holder is fitted with a catch-box F to collect any condensed water or tar, and the gas passes to the outlet cock E and supply pipes.

In the original Sardi apparatus the carbide was all contained in one long cage, but this gave rise to such serious overheating that it was afterwards subdivided into a number of small cells, which to a great extent diminishes this trouble.

The generation of gas in this apparatus is controlled by the rising of the holder, which withdraws the carbide from the water as it rises, and again brings it into contact with the water as it falls.

The Liver generator

Another generator, of much the same construction,

in which the make of gas is regulated by the movement of the gasholder, is the Liver or Sovereign, Fig. 120. In this apparatus the moving bell A is provided with a central tube, in which is placed the carbide holder, the opening being rendered gas-tight by a screw clamp. The carbide holder consists of a number of cells, in which the carbide is placed, threaded on a central support, by means of which the cells can be withdrawn or replaced.

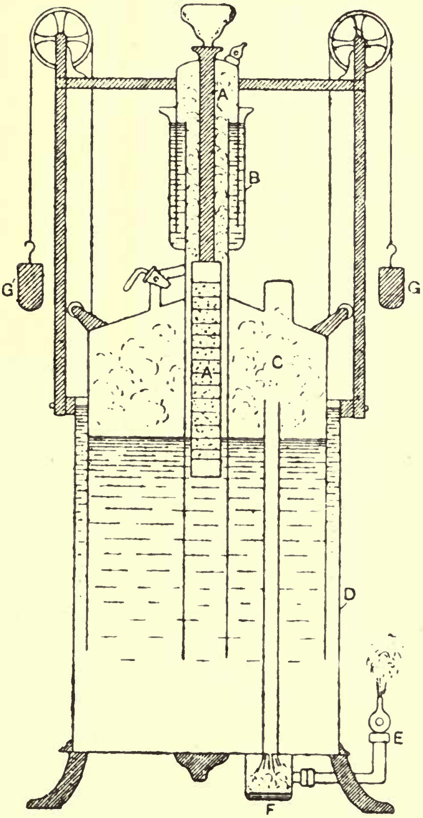


FIG. 119.

General arrangement of the apparatus

At one side of the gas generator, at the bottom, is the gas outlet, fitted with tap D, and having under it a tube with screw cap E containing a sponge for filtering the gas. On the other side of the generator is the outlet B in connection with the safety escape valve situated in tube I, and to which a pipe carried outside the building should be fixed. The tap C permits of the water chamber being emptied when required. By means of the tap F communication between the gasholder and the carbide can be cut off,

and this is employed when the generator has to be charged, whilst the lights are still being used.

The Abingdon generator

The Abingdon generator is automatic in action, the contact of water and the carbide being controlled by the rise and fall of the gasholder. Fig. 121 gives vertical and horizontal sections of this apparatus.

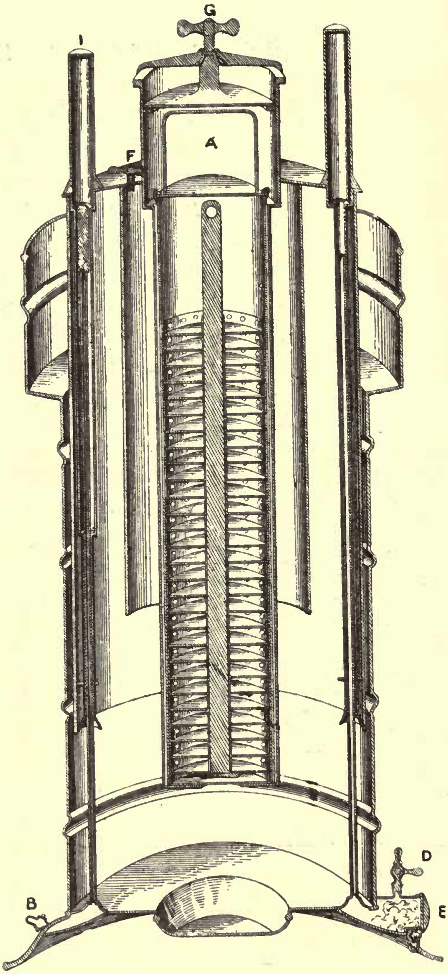


Fig. 120.

Construction

A square water tank A contains the moving gas bell B, within the hollow centre of which is fitted the inverted cylinder C, which acts as a generating chamber, and also serves as a relief gasholder if an undue pressure of gas should arise. Between the gasholder B and the generating chamber C a cylindrical open-topped vessel *d* provided with a central tube is placed, resting on the floor of the tank A. Around the central tube perforated cages for holding the carbide are disposed

at varying heights, so that the water can attack the carbide in successive portions. The whole arrangement of generating chamber c, the bucket *d*, and

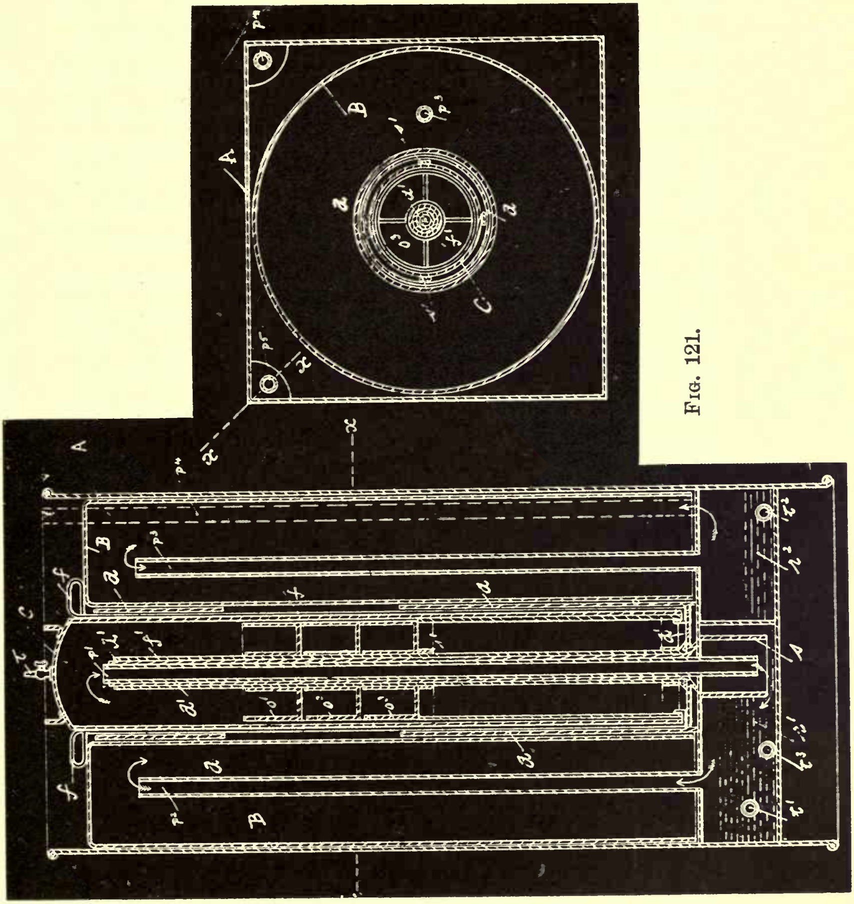


Fig. 121.

supporting framework for the carbide cages, works upon a central gas pipe, the lower end of which leads into a water seal to prevent a back flow of gas to the generating chamber. Owing to the generating cham-

ber c and holder b being surrounded by water the gas is delivered to the pipes in a cooled condition.

Caro on the relative heating with generators of the "Drip" and "Dip" types

Dr. N. Caro,[1] in contrasting the heating effects produced in those forms of apparatus in which the water drips on to a mass of carbide, and those of the last class, says:—"At first sight the 'dip' generator appears to have a great advantage over the 'drip' generator because a great quantity of water comes in contact with the carbide. This should apparently prevent excessive rise of temperature, as a portion of the heat of the reaction would naturally be taken up by the water. In reality, however, the generation of the gas does not take place under such improved conditions. In all types of 'dip' apparatus, water touches the carbide only momentarily, the carbide absorbs water, acetylene is evolved, and the water is driven away from contact with the carbide. The absorbed water then acts on the carbide, which is now in excess, just as in the 'drip' generators, but the reaction takes place between greater masses, and the generation happens freely on all sides of the carbide. The result is, that the development of heat is even greater. Among ten experiments with 'dip' generators, alloys melting at 240° C. (464° F.) were fused in two cases, and in one instance an alloy melting at 280° C. (536° F.) showed signs of fusion."

Temperatures observed

Lewes' experiments on the heat evolved

Lewes[2] made experimental determinations of the heat evolved in generators of these two classes, and found that under certain conditions the whole mass of carbide might become red hot. These experiments and results have been to a certain extent misunderstood. It was by no means intended to convey that such temperatures were of common occurrence, or that all generators of the "drip" and "dip" classes were of necessity liable to overheating of the character

[1] *Zeit. f. Beleuchtungswesen*, 1898, 10, 34.
[2] *Journ. Chem. Soc. Ind.*, xvii.

found: the intention was to determine how high it was possible for the temperature to rise under the worst conditions, as it is manifest that it is only by knowing this that safety can be secured, and wrong forms of apparatus eliminated.

Measurement of Temperature

In all the experiments the temperatures existing in the mass of decomposing carbide were measured by the Le Chatelier thermo-couple, as preliminary experiments showed that thermometers or strips of alloy of known fusing-point were useless for this purpose.

The use of the Le Chatelier thermo-couple for the determination of temperature is now becoming so general that a description of the necessary precautions in employing it will not be out of place.

The Le Chatelier Thermo-couple

The thermo-couple of platinum and platinum-rhodium wire was connected in series with a dead beat galvanometer—Ayrton and Mether's pattern—and a resistance of 19·15 ohms was introduced into the circuit. The galvanometer was calibrated by means of a cell of small internal resistance and a box of high resistance coils; and, on plotting out the currents and deflections, a straight line was obtained, showing that within the limits of the scale the deflections were directly proportional to the currents.

Wires employed

The platinum and platinum-rhodium wires used for the thermo-couple were 0·011 inch in diameter or 0·279 mm. The resistance of the platinum wire per metre was 1·71 ohms, that of the platinum-rhodium wire being 3·6 ohms.

Calibration of the thermo-couple

The couple was calibrated with every possible precaution, immersion in a paraffin bath, the temperature of which was checked by a standard thermometer, being used to fix the points up to 300° C., whilst the boiling-points of sulphur and tin protochloride were taken to give 448 and 606° C., whilst above this point it is now well known that the line is perfectly straight.

Precautions necessary in using the Le Chatelier couple

When very high temperatures are recorded, especially in the presence of acetylene, the couple must again be compared with substances of known melting or boiling-point after every few tests, as the metals forming the couple rapidly become affected by the carbon and record too low, there being sometimes as much as 120° C. difference between the temperature as given by a new couple and one which has been used for some time and which has become carbonised. If these precautions be observed, the thermo-couple is undoubtedly the most accurate means we have of recording all temperatures up to 1,700° C.

Tests with dripping apparatus

The first set of experiments was made to determine the temperature generated when water drips upon carbide, and considerable difficulty was found in arranging the apparatus in such a way as to make it a fair test of what really takes place in practice. After several failures, the form of apparatus which was finally adopted was as follows :—

Arrangement of apparatus

A cylindrical cage of wire gauze, for holding the carbide, was stood in a porcelain dish, supported by an iron tripod standing in the circular dish which acted as a mercury seal for the bell jar. The tubulure of the bell jar was closed by a cork, carrying the two glass tubes insulating the thermo-couple, the dripping funnel fitted with a stop-cock and a double jet at its lower extremity, and a wide brass tube, closed with a cork, through which passed the delivery tube.

Method of conducting the experiment

Having about half filled the cage with carbide, analysing 91·3 per cent., it was placed in position, standing on a piece of asbestos card in the porcelain basin, and the bell jar placed over it, the bottom being sealed with 2 cm. of mercury in the bottom dish. The cork was put in position (the thermo-couple being raised or lowered until it was at the required depth) in the carbide cage, which was then filled up over the couple by dropping in carbide through the brass tube.

When the quantity of carbide to be used had been charged in, the brass tube was closed by a cork carrying the delivery tube, which in turn was connected to a condenser and collecting bottle, and the water was run in in known quantities by the dripping arrangement, readings of temperature being taken every minute.

Size of charge used

The charge of carbide employed in every case was half a pound; and a very large number of experiments was made, as it soon became evident that, owing partly to the non-conducting properties of the lime formed, which in many cases crumbled off from the surface of the decomposing carbide and coated the thermo-couple, and partly also to the couple only being about 7 mm. in length, and so only recording the temperature of a very small portion of the charge of carbide, the temperature readings were often manifestly too low, as actions, such as the formation of tar vapours, could be observed going on in parts of the charge, whilst the thermo-couple was registering a temperature of 200 or more degrees less than was known to be needed for the actions visibly taking place.

Dis-crepancies in the results

Factors leading to false results

Moreover the streams of water impinging upon the carbide must not flow directly on to the thermo-couple, or it is manifest correct readings cannot be obtained.

The first dozen experiments were necessary to show the various factors which had to be taken into account in making the determinations; and when the necessary experimental conditions were realised, then the determinations began to show something like uniformity in results.

The following test may be taken as being typical of the results obtained—showing how serious the overheating may be in generators of the "drip" class:—

Experimental results

Thermo-couple Readings per Minute.

227 grms. of carbide used, and 330 grms. of water dripped on during the first 40 minutes.

Minutes	°C.	Minutes	°C.	Minutes	°C.	Minutes	°C.
1	—	16	452	31	558	46	417
2	97	17	616	32	554	47	420
3	154	18	648	33	553	48	425
4	103	19	674[1]	34	551	49	423
5	182	20	644	35	530	50	421
6	204	21	630	36	503	51	417
7	209	22	623	37	497	52	414
8	218	23	625	38	470	53	402
9	213	24	623	39	430	54	398
10	244	25	619	40	393	55	390
11	250	26	616	41	417	56	387
12	265	27	600	42	418	57	383
13	284	28	580	43	417	58	375
14	290	29	580	44	415	59	373
15	217	30	572	45	418	60	373

The condition of the Lime residue often an index to the temperature generated

The lime residue in generators of the class in which a mass of carbide is dipped into water and then withdrawn by the rising of the holder is often noticed to be yellow and pasty from the admixture of tar, whilst sometimes it is covered with a surface coating of carbon, phenomena which could only be accounted for on the supposition that the temperatures had been very high, and in the latter case had exceeded 780° C., the decomposing point of the acetylene.

Experiments were then made to see what temperatures could be attained in generators of this construction.

Experiments on the temperatures generated in "dipping" apparatus

The same bell jar was used as in the former set of experiments, the arrangement of cork, tube for charging, thermo-couple, and delivery tube being also the same, but the cage carrying the carbide was suspended to the cork, whilst a collar fitted around the neck of the bell jar admitted of its being made into the bell of

[1] Maximum reading.

a gasholder by suspending it in a glass tank of water, lines attached to the collar being passed over pulleys in a frame above, and so arranged as to allow the bell to be counterpoised.

Arrangement of apparatus

The couple was so arranged as to have a central position in relation to the walls of the holder, and to be about three-quarters of an inch (17 mm.) below the surface of the carbide, the twist of platinum and platinum-rhodium being as before about 7 mm. in length.

Conditions of experiment

The charge of half a pound (226·8 grms.) of carbide having been introduced into the cage with the thermo-couple in position, the counterpoise weights were removed, and the cock on the delivery tube being opened, the bell sank in the water until the carbide cage reached the surface, when the sudden evolution of gas caused the bell to again rise, until the rate of delivery exceeded the rate of generation, when it again sank and immersed the carbide, this action continuing until the carbide was all decomposed.

Position of thermo-couple

The thermo-couple being in the upper part of the charge, the rise of temperature is not at first shown, but as the action approaches the neighbourhood of the couple it registers a rapid increase of temperature, and the action going on is generally rendered invisible by the steam, white vapours and even brown tar fumes coming off from the lower portion of the charge.

Time taken to generate the maximum temperature

In from 12 to 18 minutes from the start, the maximum temperature is reached at the spot affecting the couple, and soon after the temperature falls as rapidly as it rose.

The following Table gives the temperature readings in four experiments:—

Experimental results

THERMO-COUPLE READINGS PER MINUTE.

Minutes.	° Centigrade.			
	I.	II.	III.	IV.
1	...	...	...	...
2	...	...	...	...
3	...	...	80	...
4	...	...	122	...
5	102	137	170	...
6	119	178	218	...
7	180	200	254	150
8	204	246	287	178
9	227	288	326	233
10	249	338	413	245
11	270	413	727	342
12	298	620	**754**	393
13	336	**734**	568	764
14	408	727	466	793
15	464	706	428	**807**
16	594	701	385	793
17	**703**	636	347	764
18	654	597	168	725
19	570	478	131	623
20	514	381	...	577
21	443	254	...	594
22	190	...	...	252
23	123	...	..	124
25	96	...	...	...

Conclusions

From this it is seen that excessive heating took place in every case, whilst in one it was well above the decomposing point of acetylene, a thin cloud of black smoke being formed immediately around the carbide, whilst tar vapour poured off from it, and on removing the residue after the experiment it was found to be coated with soot and loaded with tar.

On several occasions the whole of the charge, on removal from the generator when the maximum temperature was reached, was found to be at a glowing red heat, and it was a striking fact that the smell of acetylene could hardly be distinguished in the strong tarry odour that was evolved.

Effect of heat on Acetylene

The moment that acetylene is subjected to the action of high temperatures changes of great complexity at once commence. These at first are purely synthetical; at temperatures which are low as compared to those which are described above the acetylene begins to condense to benzene; as the temperature rises the condensation of four molecules of acetylene yield styrolene; a further increase in the temperature may cause styrolene and benzene to interact, yielding anthracene and hydrogen, and it is probably at this point that the brown tar vapours appear, while naphthalene makes its appearance. These changes, however, still have to be accurately studied. At this temperature, moreover, a fresh set of interactions start: the nascent hydrogen combines with acetylene to form ethylene, and this body, under the action of heat, breaks down to methane and acetylene once more.

Production of Benzene and Tar

Formation of other Hydrocarbons

Haber's results

The earlier actions of necessity lead to a great loss in the volume of the acetylene. Dr. Haber found that 15 litres of acetylene, when heated for a considerable period to 638° C., left only 10 litres of gas.

Action in the generator

Probably no such condensation as this takes place in an acetylene generator. When the outer layer of carbide decomposes, the gas is evolved so rapidly that there is no time for the heat to act upon it, but as the decomposition spreads into the centre of the mass, the acetylene generated has to pass through the external layers, which, as shown, may be at a temperature above the point of its decomposition, and it is under these conditions that a considerable loss takes place, and the tar, often found in the residue, or distilled out into generator and tubes, is formed.

Troubles with the Polymerisation products

In generators in which excessive heating takes place, this tar is likely to cause considerable trouble, as it is of a very viscous character, and if it condenses in the delivery tubes, causes the lime-dust and carbon particles to collect and bring about stoppage.

Alteration in the composition of the gaseous products due to overheating

A still more important evil, however, is to be found in the alteration which takes place in the composition of the gas, and which reduces the illuminating value of the gas to a serious extent.

Analysis of gas produced

During one of the experiments samples of the gas were taken as the maximum temperature was approached, and were analysed with the following results:—

—	I.	II.
Acetylene	70·0	69·7
Saturated hydrocarbons . .	11·3	11·4
Hydrogen	18·7	18·9
	100·0	100·0

and this alteration in composition reduces the illuminating value of the gas from 240 candles to about 126.

Troubles due to the formation of Benzene

If the temperatures determined in these experiments be arranged as curves, in which time and temperature are taken as factors, it is at once apparent that a very considerable proportion of the generation takes place at a temperature above 600° C., about which point polymerisation commences. As benzene forms a large proportion of it, it is carried forward as vapours, and remains suspended, even in its passage through the gasholder and delivery pipes. Benzene requires three times the volume of air for combustion that acetylene does, and the result is that the most perfect acetylene burner shows a tendency to smoke directly any quantity of benzene is formed.

The first Carbide into water generator

It was Dickerson who first made a generator in which carbide was fed into an excess of water, and took out a patent for it in December, 1894. He used pulverised or granulated carbide contained in a hopper, at the bottom of which was a valve automatically controlled by the rise or fall of the gasholder, and which allowed

the carbide as required to fall into the water in the generator beneath, the water in which was kept at a constant level.

The Pictet generator

Later on Pictet made a generator in which carbide was thrown by hand into water which was kept at a low temperature by a coil of pipe through which ice-cold water could be made to flow. From the first it was recognised by scientific men that adding carbide to water was the right way to generate the gas, but it had one drawback. The generator inventors were bitten with a craze for making automatic generators and doing away with a store holder that should contain enough gas for the evening's consumption. It was fairly easy to do this if one had merely to regulate the dripping of a liquid like water, but very difficult when a solid like calcium carbide had to be dealt with, and the result was that the first big class of generators, in which the water was brought to the carbide, was devised wholesale, whilst the carbide into water class was neglected. It was not long, however, before the demand for generators of this class led to attempts being made to overcome the problem, and although a thoroughly satisfactory solution has hardly yet been arrived at, still there are several fairly satisfactory automatic generators of this class. The means adopted for feeding the carbide automatically into water are:—

The facts which militated against the introduction of Carbide into water generators

Means mostly adopted for the automatic feeding of Carbide into water

1. By allowing granulated carbide to be fed by gravity from a hopper, closed at the bottom by valves of various construction worked by the rise or fall of the holder.

2. Drawing carbide from a store holder, and dropping it into water by the revolution of a worm or screw.

3. Unlatching the bottom of holders containing carbide, so as to discharge the contents into water, or making a series of bottomless holders, filled with car-

bide, slide on a metal plate over a hole, through which the carbide falls into the water.

4. Automatically dropping vessels containing carbide into water in a generator; this latter class hardly belonging to this type of generator, as the infiltration of water to the carbide vessel really makes it a water to carbide machine.

Omitting the mention of some of the more complicated forms of apparatus, which seem to have been designed more with the view of displaying the ingenuity of the inventor than of safely making acetylene, it will be well to describe some generators in which the above methods are utilised.

"Valve" Generators.

The Acetylite generator

The Acetylite.—This generator consists of an inner and outer tank placed concentrically on a base plate, with a gas bell fitting in between the two tanks. On the top of the gas bell is a neck of smaller diameter C (Fig. 122), closed at the top by a cover with screw clamp, and in which is hung a conical carbide hopper fitted at the bottom with a conical valve D, which rests on a suitable seat, and has attached to its underside a rod and weight W. From the crown of the gas bell is also hung a perforated grid F, fitting freely in the inner tank, into which it projects when the bell is in place. The gas exit pipe and raising rod pass freely through holes in this grid.

Construction of the generator

On the base plate are fitted a water cock, sludge cock, and gas cock, and a screw is affixed so as to enable the raising rod to be set at any required height.

Granulated carbide is fed into the hopper on top of the gas bell, and the opening made gas-tight by screwing down the cover. As the bell sinks, the weight of the valve strikes the raising rod G, causing the valve to lift, and allowing carbide to drop into

the water. With the rise of the bell the valve again closes, shutting off the supply of carbide.

In the Sigurdsson generator, Fig. 123, granulated **Sigurdsson generator**

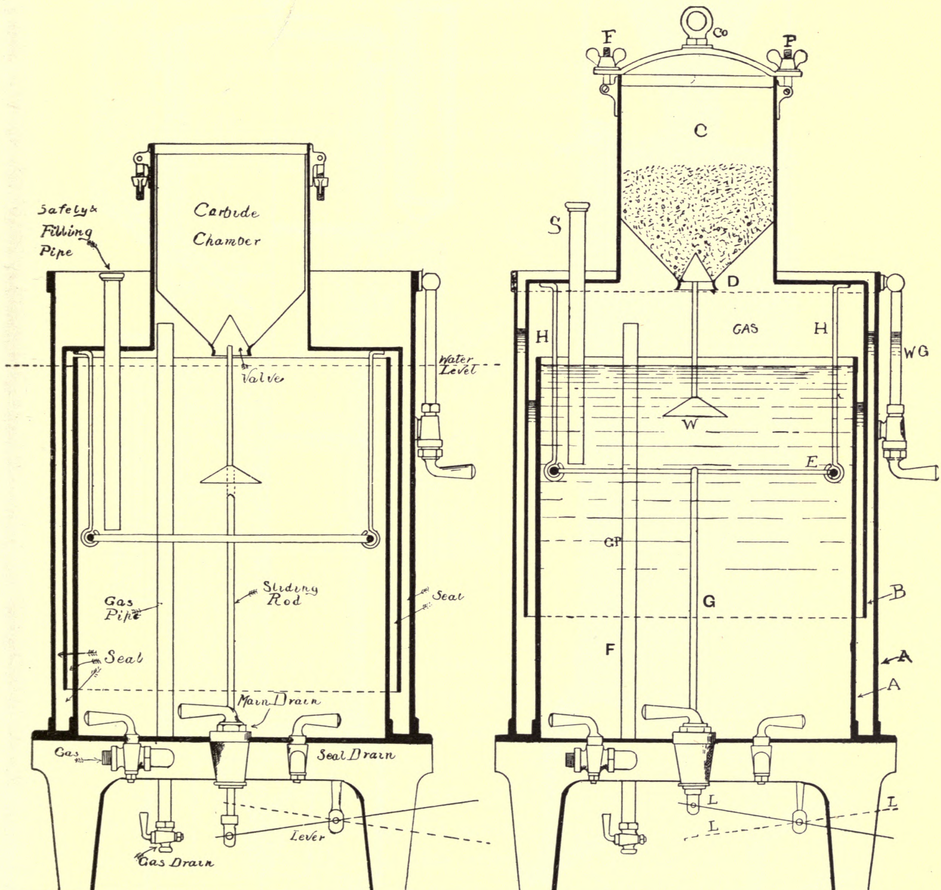


FIG. 122.

carbide is contained in a conical hopper fixed to the top of the bell of the holder. This hopper is closed by a sliding valve connected to a shaft having a

slotted lever arm, which works on a pin fixed in one of the uprights of the holder.

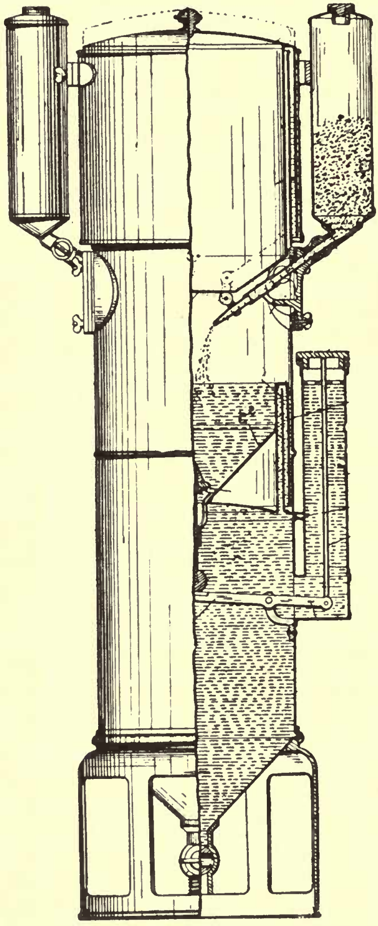


Fig. 124.

Fig. 123.

Working of the generator

As the bell of the holder descends, the lever arm is raised by the pin and draws open the valve, thus

allowing a charge of the carbide to fall upon a perforated conical disc, placed just below the water in the tank. Acetylene is generated, and as the bell rises the lever is pressed down and slides the valve back into position, so cutting off the carbide supply.

In Ross' generator the automatic supply of granulated carbide to water is brought about by fitting on the top of the generator a small rising holder, containing a hollow drum a^3. The carbide is contained in two **Ross' generator**

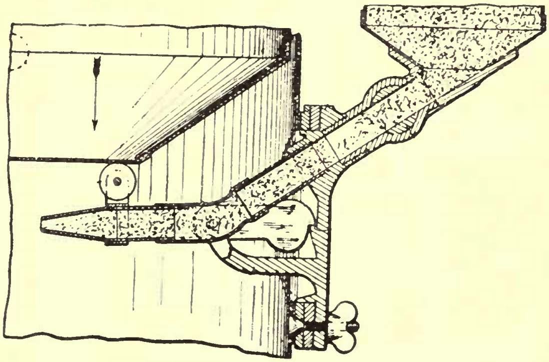


Fig. 125.

hoppers H H fixed on the exterior of the apparatus, having a delivery spout *h* projecting into the generator. This spout is some inches in length, and its central portion is made of flexible tube, whilst the nozzle is carried by *w*, a weighted lever, working on a bracket, which, when the drum in the holder is raised, lifts the spout upwards and stops the outflow of the carbide, but which, as the drum descends, is pressed downwards and allows the outflow of carbide into the water. Reference to Figs. 124 and 125 will at once make the inventor's intention clear, but one would expect that the arrangement, although highly ingenious, would soon get out of order and clog. **Construction**

"Screw" Generators.

The "Strode" generator

In Strode's generator, the process of dropping the carbide into water as more gas is required is carried out automatically by means of a water wheel actuating a cone, having a spiral chamber, into which the carbide falls by its own gravity, a portion being turned into

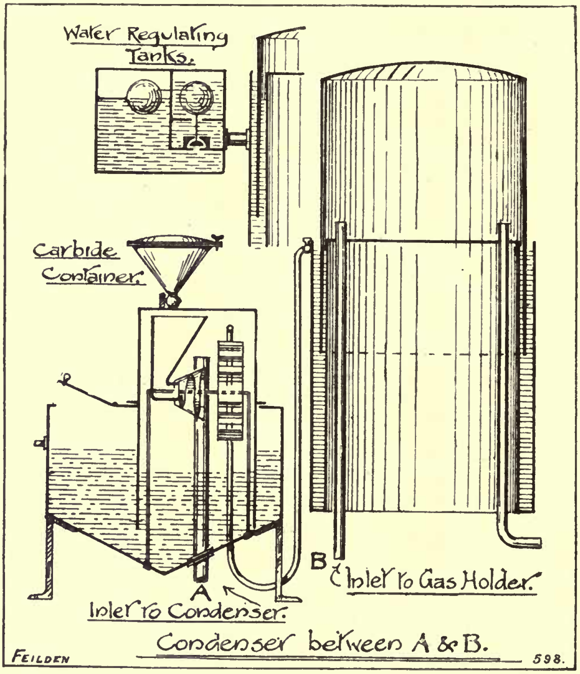


Fig. 126.

Construction and working of the generator

the water with each movement of the water wheel. The water acting on this wheel is regulated by the rise and fall of a small gasholder, slightly larger at the top than at the bottom, the walls of the gasholder displacing the water in the holder tank, so that it overflows on to the water wheel, which is provided with pockets, and on one of the pockets becoming filled the wheel gives a quarter turn. The cone piece, being on

the same spindle, is turned with the wheel, and the carbide, gravitating through the spiral chamber, falls into the water beneath. The water projected from the wheel serves to replenish the water absorbed in the generation of the gas. A water-regulating tank is provided for connection to the water main, with double ball valves and overflow to maintain a constant level of water in the gasholder tank when the gas is not being used.

The process of charging the generator with carbide and dealing with the sludge and cleaning out is effected very simply. An overflow is provided to the generator, arranged in such a way that any surplus water in discharging into an overflow tank provided, carries with it the lime formed in the generation of the gas.

A connection is also made between the overflow tank and the generator with full-way valve, so that the sludge and lime can be run off into the overflow tank without interfering with the working of the apparatus in any way.

The working part of the generator is covered by a box-shaped cover, open at one end, which slips over the carbide container and water wheel and dips down some distance into the water, thus forming a perfect gas seal, and can be instantly removed or replaced. At the top of this cover is a hopper connected to the cover with a valve. When this hopper requires recharging the valve is closed to prevent the escape of gas from the generator, or the admission of air, and the hopper being opened is then filled with carbide; and, after being closed, the valve connecting it with the generator is opened, and the carbide is free to run into the water contained beneath.

Arrangement of Carbide hopper

The Szepezynski generator

Another generator in which a worm is used to discharge the carbide into the water is that designed by Szepezynski, Fig. 127. It consists of a tank generator

A, with the apparatus for supplying the carbide fixed on the top. The latter is an iron cylinder with an axle passing down the centre, which carries a screw work D. The screw chamber is filled with carbide through the cover C, and as the gasholder falls it releases a rope passing round a pulley on the end of the axle; the rope carries a weight on its free end, and this causes the axle and screw to rotate, and throws some of the carbide on to the trap valve E, which opens and

Construction of automatic feed

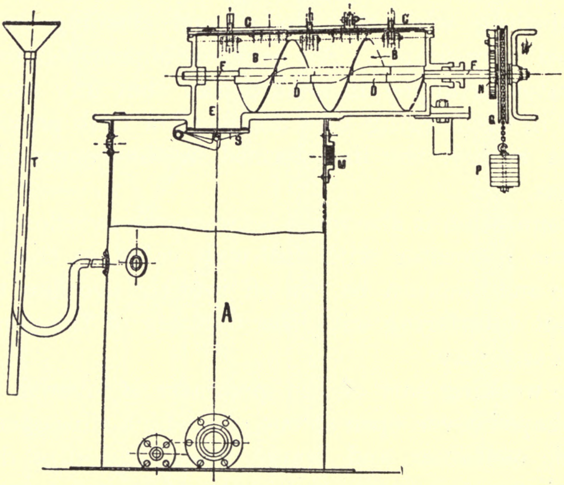


FIG. 127.

allows it to fall into the water below. As the gas is generated and the holder rises, the rope is again pulled taut and the weight lifted, the pulley running free; and on the holder again falling, the previous operation is repeated, and more carbide is shot into the water in the tank.

Bertrand-Taillet generator

"*Latch*" *Generators.*—The "latch" generator in its simplest form is to be found in the Bertrand-Taillet apparatus, Fig. 128, in which the fall of the holder empties small charges of carbide in rotation into the water contained in a compartment occupying the

centre of the holder tank. The gasholder bell C works in a water trough formed by the space between the two cylindrical vessels A and B. The interior of A forms the generator, and is filled to the required height with water, whilst a series of carbide vessels D are fixed in the top of the holder.

Means of discharging the Carbide into the water

These carbide vessels have hinged bottoms, which are kept shut by counterweights suspended on strings or wires of varying length, and are closed above by gas-tight lids. As the holder descends, the weight attached to the longest string comes in contact with the bottom of the generator and releases the carbide from the vessel to which it belongs; acetylene is then liberated and the holder rises, and on again descending the charge in the vessel with the second longest string is discharged, this action continuing until all the carbide has been shot into the water.

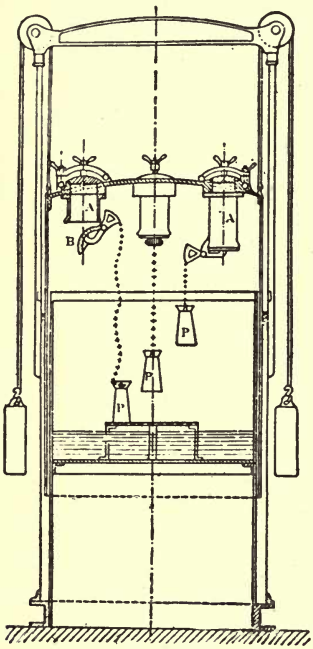


Fig. 128.

The Gibbs generator

A rather more complex form of the "Latch" type of generator is found in one of the few carbide-into-water forms of apparatus devised in America. The Gibbs generator consists of a gasholder and generator placed side by side. The gasholder carries at its side a long water seal consisting of two concentric tubes having a water space between them. The inner tube carries the gas into the holder, whilst the outer com-

municates at its lower extremity with the water in the holder tank. A tube from the generator telescopes in between these, forming the seal. On the top of the generator is a revolving plate carrying the carbide holders on its edge. These holders are fitted with a hinged cover kept shut against a rubber washer by means of a spring latch, and they are placed lid downwards at the edge of the plate. The plate is caused to rotate by means of a ratchet and pawl operated by the movement of the gasholder, and as the bell descends the plate carrying the carbide holders is revolved until the hinged lid is opposite the mouth of the generator shoot, when the latch is released by its trigger hitting the edge of the shoot, thus allowing the contents of the carbide holder to drop down the shoot into the water in the generator. The gasholder then rises, and the pawl is ready to revolve the plate another step when the holder again descends. The long telescopic seal on the side of the gasholder permits sufficient vertical motion for the gasholder, and the reduced lime is removed by detaching the generator bodily from the apparatus and emptying it, a water seal preventing any escape of gas from the holder.

The automatic Carbide supply

French automatic Carbide into water generator

A generator working on the principle of carbide dropping into water, and which is simple in construction, is the revolving apparatus made by the Société du Gaz Acétylène, and shown in Figs. 129, 130, and 131. In the head of the generator is a metal drum M carrying the carbide, chambers which are open at the bottom, and capable of being rotated by the weight P fixed to a rope coiled round the drum passing over the pulley *g*. This drum M works on a fixed plate N, in which is a hole corresponding with the open base of the carbide chambers. On the outside of the drum metal pins are attached, corresponding to each carbide chamber, whilst to the bell of the gasholder the

Construction and working

weight Z is fixed. To the head T is fixed a bracket V carrying a pivoted arm, the end of which nearest the head is forked, whilst the other terminates in a metal plate U. In practice, as the holder descends, the weight Z strikes the plate U, causing the top arm of the fork to rise and releasing one of the pins outside the drum M. This allows the drum to rotate till it is

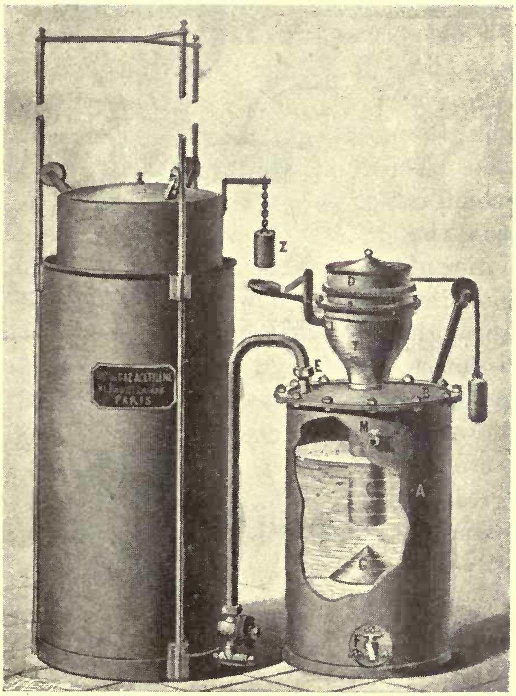


FIG. 129.

stopped by another pin catching in the lower arm of the form. At this point the opening in the carbide chamber is exactly over the hole in the fixed plate N, and, therefore, the charge of carbide drops into the water in the tank below. With the evolution of gas the holder rises, bearing with it the weight Z; a

spring *z* then pulls up the lever arm and allows the drum M to rotate until stopped by the upper pin of the next carbide chamber engaging with the top arm of the fork, closing the opening in N, and in this position it remains until liberated by the descent of the bell. The carbide falls through the pipe C into a cone G in the water, the object of which is to prevent the accumulation of the carbide into heaps. The lime sludge can be removed through the cock F.

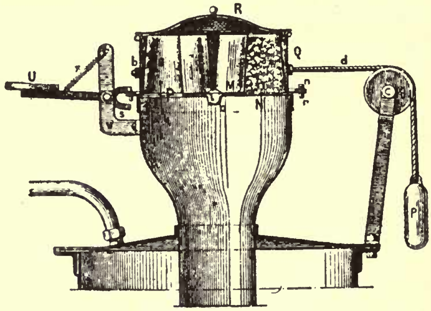


FIG. 130.

Non-automatic Carbide into water generators

Non-automatic generators of this class lend themselves to the greatest possible simplicity of construction, perhaps the most simple apparatus made being that designed by the Acetylene Gas Company of Australasia, and called "The Perfection," which consists of a gasholder working in a tank with a conical bottom, having at the lowest point a sludge cock for the withdrawal of lime sludge and a tap for the introduction of fresh water. At the point where the

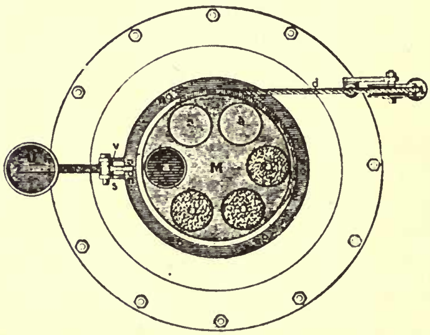


FIG. 131.

cone and cylindrical tank meet is a grid upon which the carbide falls, whilst in the top of the bell of the holder is fixed a tube of sufficient diameter to allow the carbide to be dropped down it. This tube is closed at the top and bottom by covers working on the same axle, so that the opening or closing of the exterior one opens or shuts the one at the bottom of the tube. The carbide tube is of the same length as the height of the gasholder bell, so that it will be always sealed with a few inches more water than the bell, the extra depth depending on the pressure of gas in the holder. To make acetylene the sliding covers are opened, the carbide dropped down the tube, the covers closed, and the gas generates and fills the holder. The only drawback to such a generator is that a loss of gas is occasioned as the carbide falls through the water in the tube, but if fair-sized lumps are employed this is small. The dust and small carbide is, in the more modern form of this generator, utilised in a small drip flask at the bottom of the apparatus.

The "Perfection" generator

Working of the apparatus

The next generator in order of simplicity is the "side chute" type, in which the generator is separate from the holder, and consists of a water tank with grid for the carbide to fall upon and tube at the side of the generator down which the carbide is dropped.

The "Kleine Centrale" generator

A good example of this form of generator is the "Kleine Centrale" and "Haus Centrale" of the Allgemeine Carbid- und Acetylen-Gesellschaft of Berlin—the latter of which is shown in Fig. 132, in which the carbide is dropped by hand into a side box, and falls down the side chute into the water in the generator. This contains a grid which can be cleared from any cinder that may have been in the carbide by means of a manhole, whilst sludge is withdrawn by means of a tap-hole in the bottom of the generator.

A ventilating pipe is carried up from the chute to

above the roof in order to discharge any acetylene generated during the passage of the carbide through the water in the chute into the open air.

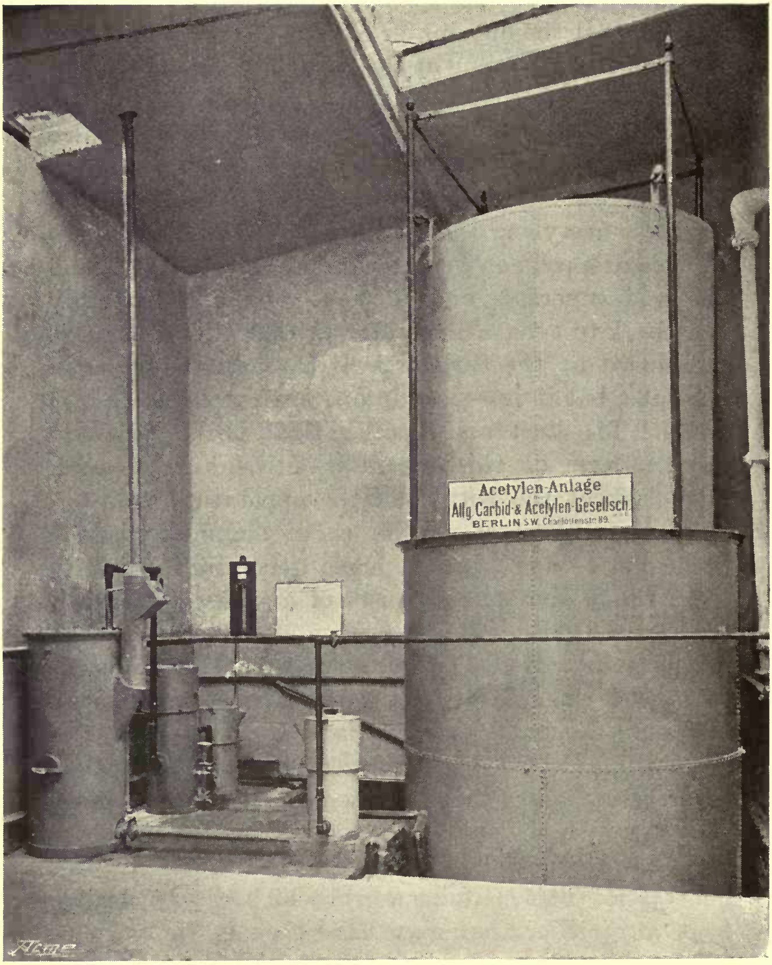


Fig. 132.

Pintsch generator

Messrs. Pintsch used to make a generator of almost identical form, but as the demand for acetylene to mix

with oil gas for compression in the cylinders used to supply the gas for lighting the Prussian railways increased, they modified the apparatus to the form shown in Fig. 133. It consists of a strong iron generator, from the top of which the feed tube or chute passes down to just below the surface of the water, which fills two-thirds of the generator.

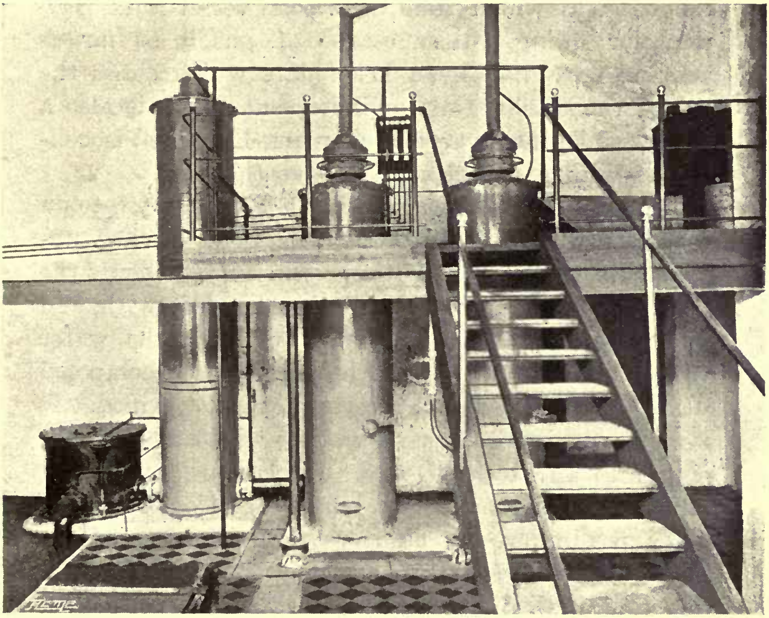


Fig. 133.

Modified form of generator

The carbide falls upon a conical deflector just below the mouth of the chute, and is spread by it over the rocking grid a short distance below. The lime residue and any pieces of carbide crust can be cleaned out by means of a sludge cock and manhole at the bottom of the generator. Water is allowed to flow in slowly but continuously through a feed pipe which dips below the surface of the liquid, and its level is kept con-

stant by an overflow pipe descending into a water seal, which acts as a safety valve in case of any stoppage causing undue pressure.

Working of the Carbide carriers

Two carbide carriers are arranged to rotate by hand on a bed plate which has an opening exactly over the mouth of the chute, and the carbide carrier which happens to be outside having been filled with carbide, is rotated until the charge is emptied down the tube, by which time the second vessel is in position for filling. Any escape of gas is as far as possible prevented by a head plate which closes the top of the discharging cylinder, but there is also a funnel which fits over the charging head, and is connected with a tube leading above the roof.

The conditions under which heating in a "Carbide into water" generator may take place

The class in which carbide is allowed to fall into an excess of water is, from a scientific point of view, undoubtedly the best, as with proper arrangements the trouble of overheating is entirely done way with, and the resulting gas in its passage through the water above the point at which the carbide is decomposed is cooled, washed, and to a certain extent purified. It seems impossible at first sight that with carbide dropping into an excess of water overheating could ever take place, but there exist certain conditions in which it is a possibility, and on more than one occasion the author has fused strips of zinc in apparatus of this kind, indicating that a temperature of 423° C had been reached. This may be brought about by certain circumstances, such as when the carbide is allowed to drop into the lime sludge at the bottom of the generator, when the heat evolved by the decomposition of a fairly large piece bakes the lime around it into a protective coating, which limits the access of water to the decomposing mass and causes the rise of temperature, and occasionally in the residue from such a generator a mass resembling a small potato will be found consisting of lime and tar baked into a hard

Protective coatings of baked lime and oil

mass containing a small kernel of undecomposed carbide.

The use of grids in this form of apparatus

Such cases are, however, rare and can be prevented by using a grid or screen on to which the carbide falls, and the lime separating during its formation goes through the meshes into the lower part of the vessel and settles there, the small pieces of carbide which find their way through the screen being insufficient in size to cause trouble of this character. Nearly all generators of this class now employ grids of this description, and even here overheating of the same character has been found, where the carbide has been put in in too large quantities so as to form a heap in one spot on the screen; lime is then liable to form over the surface of the mass, and in the interior overheating takes place, whilst, if a solid lump of carbide weighing one to one and a half pounds be thrown in, there is a liability of the same action.

Danger of adding too large a charge of Carbide or using big lumps

Loss of Acetylene from solution

It has also been urged against this class of generator that the yield of gas from a given sample of carbide is less than the yield from the same carbide used in generators belonging to the other classes, the loss being due to the solubility of the gas in the excess of water present. This objection, however, is often more apparent than real, as the less rapid rise of the holder may be due to the gas being delivered from generators of this character in a much cooler condition than from those generators which have been shown to be liable to overheating.

Conditions which limit solubility

Water at normal temperature and pressure only dissolves a little over its own volume of the gas, and this volume becomes rapidly reduced as the water gets saturated with calcium hydrate and rises in temperature, so that under ordinary conditions the percentage loss of gas due to this action would be very small, more especially if the generator is so arranged that the sludge settles freely to the bottom leaving

saturated limewater above it, and if then only the sludge is withdrawn.

Proper arrangement of grids in generator

The best arrangement to employ in a generator of this class is a treble screen placed not more than 4 to 6 inches below the surface of the water, the top screen being of such mesh that it retains the large lumps of carbide whilst the smaller lumps remain upon the second screen, the third being of such fine mesh as to practically allow only lime to pass through it. Under these conditions the volume of water through which the gas has to pass is so small a column that it merely cools and washes the gas free from the excess of ammonia and some of the sulphuretted hydrogen, without dissolving any considerable quantity of the acetylene itself, whilst the gas rising from the carbide on the second and third screens keeps the liquid round the big lumps decomposing on the upper screen so agitated that there is no risk of a coating of lime forming on their surface.

The settling of the Lime sludge

This treble screen moreover provides a haven of rest in the water below for the settlement of the lime sludge. Experiments were made to see at what rate this might be expected to take place.

Conclusions

In these experiments known weights of calcium carbide were dropped into a beaker containing a litre of water, and the results obtained were as shown in tables on following page. So that it may be said that after 30 minutes the volume of the lime is 10 c.c. per grm. of carbide, and after 90 minutes the volume of lime is 7·5 c.c. per grm. of carbide.

So that approximately after half an hour's standing each kilo of calcium carbide will give 10 litres of lime sludge, or 1 lb. of calcium carbide will yield 8 pints, which can be got rid of by a sludge cock at the bottom of the apparatus. The rapidity with which settling takes place is of course slightly affected by the form of the apparatus.

Experimental results

I

Water taken.	Calcium Carbide.	Volume of lime paste deposited during 30 mins.	90 mins.	Volume of lime paste deposited during 30 mins.	90 mins.
Grms.	Grms.	c.c.	c.c.	Calc. for 1 grm. CaC_2.	
1,000	50	480	360	9·6	7·2
1,000	50	470	340	9·4	6·8
1,000	50	440	350	8·8	7·0
1,000	50	470	370	9·4	7·4
1,000	40	430	330	10·7	8·0
1,000	40	420	320	10·5	8·0
1,000	40	400	310	10·2	7·7
1,000	40	410	320	10·5	8·0
1,000	30	340	240	11·0	8·0
1,000	30	320	220	10·3	7·3
1,000	30	330	240	11·0	8·0
1,000	30	330	240	11·0	8·0
			Mean	10·2	7·6

II

1,000	50	450	340	9·0	6·8
1,000	50	440	330	8·8	6·6
1,000	50	450	330	9·0	6·6
1,000	50	440	320	8·8	6·2
1,000	40	390	310	9·7	7·7
1,000	40	410	310	10·0	7·0
1,000	40	390	300	9·7	7·5
1,000	40	390	300	9·7	7·5
1,000	30	310	210	10·3	7·0
1,000	30	300	240	10·0	8·0
1,000	30	240	230	9·6	7·6
1,000	30	300	220	10·0	7·3
			Mean	9·5	7·2

Influence of time and the shape of generator on the condition of the Lime residue

In allowing of the settlement of the sludge, the volume occupied will of course entirely depend upon the length of time it is allowed to stand, and if a generator with holder is employed, and the make of gas necessary for the evening's consumption is stored in the holder, it will be found that by the next morning the lime will have settled in a compact mass at the bottom of the generator, with perfectly clear lime-water above it, and this lime will in many cases be

found to be so thick that it refuses to flow through the ordinary sludge cock. It is merely a mechanical question, however, to so arrange the cleaning opening that the lime can be withdrawn with a very small portion of the supernatant water, and when this is properly done the loss of gas due to the excess of water present will practically disappear.

Caro on the Carbide to water class of generator

Caro, in the paper before quoted, in speaking of this class of generator, sums up its possible disadvantages as follows: "By this method of generation of acetylene overheating is out of the question. The quantity of acetylene generated at one time is however large, and therefore ample gasholder capacity is essential. No after-evolution of gas from the carbide which has been dropped into the water is possible. In most generators of this class, the carbide receptacles have a number of divisions, the contents of each one of which are automatically discharged in turn into the water. The aqueous vapour, however, has access to the whole of the carbide in the receptacle, and therefore after-evolution does occur. But the amount of gas thus evolved never exceeds 20 per cent. of the total. In some generators of this class one carbide container only is used, and a portion of its contents is discharged into the water at one time, either through a conveying screw or a valve which is controlled by the movement of the gasholder bell. When a screw is used all the carbide is accessible to the water vapour and decomposition takes place, while in the second case carbide appears invariably to stick between the valve and its seat, and thus prevents the effectual closing of the valve. Generators of this class are quite trustworthy, but care should be taken that a gasholder capable of receiving at least one-fifth of the gas which the carbide in the container will yield is attached to each."

Troubles likely to occur with automatic generators of this class

In many forms of what are apparently at first sight

carbide-into-water generators, the carbide is enclosed in a tin, or some other form of container, which is plunged under the surface of the water in the generator. Such forms are of course more nearly allied to the water-to-carbide class, in which the water flows into the carbide, as these containing vessels have openings of only limited size, so that instead of being entirely surrounded by water, the water is only slowly infiltering to the carbide through the openings, and in this class of generator you find the same temperature relations existing as in those in which the vessels are flooded by the rise of water.

Generators in which Carbide enclosed in cases is dropped or plunged under water

It will now be well to summarise the influence of the type of generator on the gas produced.

1. Purity of the acetylene.

It may be accepted that the purity of the gas produced will be inversely as the heat generated during its production, *i.e.* the lower the temperature of generation the purer will be the gas, and it is manifest therefore that apart from the washing influence of the water present, the last class of generator will give the purest gas, whilst the "dip" class will give the least pure. The question, however, of the influence of temperature in the generation upon the purity of the gas will be fully discussed in the chapter on the impurities of acetylene and its purification.

Influence of the type of generator on the purity of the gas formed

2. The influence of the class of generator upon the volume of gas yielded from a given sample of carbide.

Influence of the type of generator on the volume of gas produced

The author has made experiments on between 20 and 30 different generators of the various classes, making from each an average of 600 c. ft. of gas, and using carbide from bulk of even composition. Under these conditions very varying results were obtained, some generators showing themselves capable of evolving the same volume of gas from the carbide

that had been determined by laboratory experiment, whilst others of the same class gave far lower results; but by taking the average yield of gas per unit weight of carbide from all the generators of one class, it was possible to obtain data which indicated the general result.

Experimental results

	c. ft. per lb.	Litres per kilo.
Water dripping on carbide	4·3	267·7
Water rising to carbide	4·4	273·9
Carbide dipped in water and withdrawn	4·4	273·9
Carbide into water	4·0	249·0

Effect of the type of generator on the residue

3. The effect of the form of generator on the condition of the residue.

As has been already pointed out, the condition of the residue left from carbide after liberation of the acetylene depends largely upon the complete decomposition of the material and the temperature at which the decomposition has been carried out; and it is of the utmost importance that there should be no risk of any undecomposed carbide remaining with the residue, as this would give rise to gas if washed away into the drains or thrown into the cesspit, and the quantity needed to yield an explosive mixture being small and the ignition point low such a mixture would be highly dangerous. In order to ensure complete decomposition generators must in every case at the end of the operation remain flooded for a considerable period, as if overheating has taken place the risk always exists of a coating of lime being baked over a small quantity of carbide, and as this resists the action of water to a great extent, it needs some time for the completion of the action. It is always better to leave the residue from one day's make flooded in the apparatus until the next occasion of making, as if the apparatus be at once cleaned out not only does the risk just alluded to exist, but it is also found that there is a certain

Importance of flooding the residue

amount of acetylene mechanically held by the lime.

Drawbacks of the "Drip" type of generator

The classes of generators in which there is the greatest risk of undecomposed carbide remaining are those in which the water drips upon a mass of carbide, as in this case it is possible that the action may be stopped before the carbide is flooded and small quantities escape decomposition. Any one who has constantly used a drip generator will have noticed that if the action has been stopped after a small amount of acetylene has been generated and the apparatus then allowed to stand for a day or two, although there may be a large amount of undecomposed carbide present, the water has to be turned on for a very considerable period before any fresh gas is evolved, this being due chiefly to the lime formed during the slow after-generation forming a very tough adhesive coating over the surface of the undecomposed material, this coating consisting largely of lime next to the carbide, whilst on the exterior it is chiefly calcium hydrate.

The influence of the type of generator on frothing

4. The influence of the generator on frothing.

In those forms of generators in which carbide is in excess, frothing is practically an unknown trouble, but where water floods a vessel of carbide, or where the carbide is dropped into water, trouble may sometimes arise from formation of foam on the top of the liquid. When the carbide is dropped into water, at first no foaming occurs, but as soon as the water begins to get fairly saturated with lime frothing commences,

Cause of frothing

and is due to the fact that, as the bubble of crude acetylene leaves the carbide and passes up through the saturated limewater, the impurities in that particular bubble are absorbed on the exterior of the surface and form a thin vesicle round the bubble, having a different composition from the remainder of the liquid. On reaching the surface these vesicles often remain for a moment as a covering to the gas just evolved, and in this way mounting up form the foam.

Means of preventing frothing when working on a big scale

If in the expansion of acetylene illumination on a large scale this is found to be a very serious trouble, it can readily be got over by methods of the same character as those adopted in fermentation vats, where a thin arm rotating at a high rate of speed breaks up the scum as it forms.

Carbide into water generators a necessity in installations on a big scale

With the introduction of acetylene for the lighting of small towns and villages by distribution from a central generating station with holders, it has been found that it is only the carbide-into-water class of generator that can be employed with success, as directly one begins to deal with large weights of carbide the temperature factor becomes so serious that one must either divide the charge up into a multitude of small generators or keep continuously charging and discharging the ones in use, and the result is that in practically all the Continental installations on the large scale it is this class of generator which has been adopted.

The following list (page 425) will give an idea of the acetylene supply works at present in operation or well advanced in construction, and where possible the price charged for the gas per 1,000 cubic feet is also added.

The Installation at Oliva

The method employed and the general arrangements are very much the same in all of them, and a description of the installation at Oliva will serve to give an idea of the way in which they are carried out.

The installation consists of six producers, made by the Allgemeine Carbid- und Acetylen-Gesellschaft of Berlin, four of which are in use, and can produce 10 cubic metres per hour, whilst two are held in reserve. If necessary, however, a larger output of gas could be made. These generators are placed in two groups of three, with a platform between them for convenience in feeding in the carbide.

List of towns using a central Acetylene supply, and prices charged

Country and Name of Place.	Number of Inhabitants.	Price per 1,000 c. ft.
GERMANY—		£ s. d.
Hassfurt	2,500	3 8 0
Oliva	2,000	3 10 9
Schonsee	1,536	
Ellerbeck	4,176	
Grossenlinden		3 19 3
Daaden	1,767	3 2 3
Strelitz	5,000	2 13 9
Treptow	4,363	
Peiskretscham	4,500	
Achim	3,500	
Sulzburg	1,111	
Allandorf and Soden	6,000	
Schlagenbad	2,000	
Durenberg		
Guttstadt	4,504	3 10 9
Johannisburg	3,000	
Passenheim	1,967	
Sensburg	3,562	
Ratzebuhr	2,298	
Friedland	3,598	
Arys	1,324	
Bischofswerder	1,748	
Frauenburg	2,458	
Saalfeld	2,517	
HUNGARY—		
Mezotur	23,800	
Totis	11,000	3 3 9
Vesprem	13,000	
FRANCE—		
Alzonne	2,000	
Cremieux	2,000	
Marcenat		
AMERICA—		
Wabash	12,500	3 4 0
New Milford	2,500	
Milford, Delaware	793	
Millbrook, N.Y.		
Corodenbeath	4,249	3 16 9

Arrangement of the apparatus

Between each pair of producers is a condenser, so arranged that it can be used either with both producers or only one, and each group of two is connected

with washers and purifiers through which the gas passes before it reaches the holder. This is a mistake, and in later installations is being altered—as whilst the generation of gas is going on rapidly, the flow through the purifiers must be too rapid to allow of proper purification, whilst had the purifying tanks been placed at the outlet for the service, a steady and continuous flow of gas during its consumption would have allowed a far better purification. The holder is of about 1,000 c. ft. capacity, and stands outside the building, and as the gas leaves it is made to pass through a drier and pressure regulator.

Output and cost of gas

This works is designed for the supply of about 2,000 flames, but at present the output is not more than half this number. The price which is charged to ordinary consumers is 2 marks 5 pfennig per cubic metre, whilst the price charged for the street lighting is at the rate of 1·7 marks per cubic metre—prices which are equivalent to £3 10*s.* 9*d.* and £2 8*s.* 1*d.* per 1,000 c. ft. respectively.

Working of the apparatus

The apparatus works smoothly and well, the gas leaving the generators at very little above the atmospheric temperature. The works are also well arranged with regard to the charging and emptying of the generators, the water for which is supplied from a storage tank kept filled by a pump worked by a Korting gas motor, which uses 300 litres of acetylene per horse power per hour, whilst a large cesspool below the generator house serves as a receptacle for the lime sludge drawn off from the bottom of the generators. On standing, the lime rapidly settles and remains at the bottom as a white mud, whilst the clear liquid can be run off from the surface into the drains, the lime residue being cleared out from time to time and used for agricultural purposes.

Distribution

The distribution of the gas is well carried out, the mains as they leave the works being 100 millimetres,

Fig. 134.—Acetylene Supply Works for 2,000 Lights.

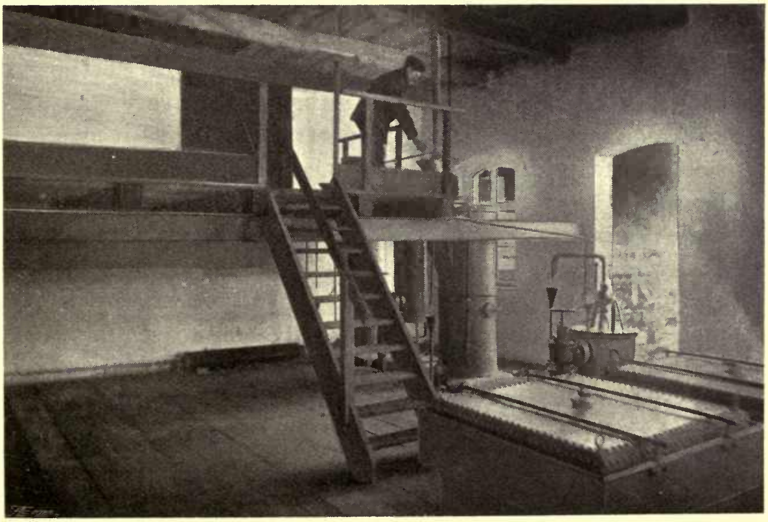


Fig. 135.—Interior of Generator House.

or, roughly, 4 inches, in diameter, and gradually tapering away as they get further and further from the works to 32 millimetres, or rather over an inch, in diameter.

The street lamps, of which there are about ninety-six, are all fitted with Munsterberg burners, which are to all intents and purposes the same as Naphey burners, and the light emitted is very effective, and, with the lamp-posts placed at intervals of 150 feet, gives a remarkably well-distributed effect.

Advantages of such installations to the Carbide trade

The great advantage of handling small town installations of this character is that, if it be done by a syndicate who are also manufacturers of carbide, only the best quality of carbide need be sold to the public, whilst the inferior samples can be utilised in providing the gas in works of this description. This is a far better solution of the difficulty of getting rid of carbide crust than the usually adopted one of mixing the inferior portions with the true carbide so as to obtain a constant yield.

The danger of large gas spaces in generators

In most generators there is a considerable amount of space filled with air before the commencement of generation, and as the acetylene comes off from the carbide this space will contain mixtures of every composition from pure air to pure acetylene; and as it may take several minutes for all the air to be cleared out from the generator space, and as the range over which mixtures of acetylene and air are explosive is an extremely wide one, it is manifest that during the early stages of generation there is always a risk of explosion taking place, more especially as the tempera-

Temperature needed to cause explosion

ture of ignition of mixtures of acetylene and air is very low (480° C), although acetylene itself does not decompose into its constituents until a temperature of 780° C is reached. The question now arises as to whether a temperature sufficient to ignite the mixture is likely or possible to be attained during the period

in which the air is still present in sufficient quantity to produce an explosive mixture.

The causes which might give rise to the necessary temperature to cause explosion

The causes which might give the necessary temperature are two in number:—

1. The liberation of spontaneously combustible gases from the impurities in the carbide which, on coming in contact with the air in the generator, might ignite the explosive mixture.

2. The generation of sufficient heat by the action of the carbide on the water to reach the ignition point of the mixed gases.

Spontaneously inflammable gases in Acetylene

In order to ascertain the likelihood of the ignition of explosive mixtures being brought about by the first cause, experiments were made by the author conjointly with Mr. Boverton Redwood to try and determine whether this were possible. The two spontaneously inflammable gases which might give rise to this trouble are the vapours of liquid phosphuretted hydrogen, P_2H_4, and siliciuretted hydrogen, both of which might be generated from impurities in the carbide under certain conditions.

Percentage of Phosphuretted

In view of the generally accepted theory of its production, phosphuretted hydrogen was made by acting on calcic phosphide with water, and attempts were made to determine what proportion of this gas had to be mixed with acetylene in order to give spontaneous ignition. It was found, however, that the mere contact with water necessitated in mixing the gases rendered the resulting mixtures non-spontaneously inflammable even when hot water was used, and that the phosphuretted hydrogen alone failed to ignite after being in contact with water for some time. Phosphuretted hydrogen was then made by acting on phosphorus with boiling sodium hydrate, and it was found that, using hot water, it required over 80 per cent. to render the acetylene and phosphuretted hydrogen mixture spontaneously inflammable.

Hydrogen needed to render Acetylene spontaneously inflammable

From these experiments it was perfectly clear that when once the mixture of gas is made, even a high percentage of phosphuretted hydrogen would be perfectly harmless, except in so far as it would give rise to deleterious products of combustion and might lower the igniting point of the acetylene, but that no risk of spontaneous ignition exists.

Conditions under which Phosphuretted Hydrogen might cause danger

If, however, one considers the methods by which the carbide is brought in contact with water in the various forms of acetylene generators, and the very high temperature which may be attained by the action of water upon the carbide, it is evident that there are cases in which water being allowed to drip on the carbide, or the dripping of the carbide into water, might give spontaneous inflammability to a mixture containing air, which, when only moderately heated, would be absolutely free from this danger.

Experiments to determine amount of Calcic Phosphide in Carbide necessary to give ignition

A series of experiments was then instituted to see what proportion of calcic phosphide mixed with calcic carbide would cause spontaneous ignition on contact with air. In order to get these experiments strictly comparable, it was necessary that the ingredients used in each experiment should be in the same state of division, and that a similar amount of water should be in each case added to the mixture.

Method of experiment

Pure crystalline carbide and fresh calcic phosphide were reduced to powder and sieved down to uniform size. Mixtures of the two ingredients were then made and put in charges of 5 grms. into small porcelain vessels, into each of which 5 c.c. of water was added, and it was found that on testing from 50 per cent. downwards, even when only 1 per cent. of calcium phosphide was present, spontaneous ignition of the evolved gases would in many cases take place, and it was also noted during these experiments that the acetylene came off more readily than the phosphuretted hydrogen, and that the ignition was gen-

erally brought about by a flash from a bubble of phosphuretted hydrogen after the first rush of acetylene had passed off. In other words, the calcium phosphide was less readily decomposed by water than the calcium carbide, so that what would be 1 per cent. of calcium phosphide in the original mixture would mean a far higher percentage by the time the calcium phosphide came to be decomposed, and it was manifest also that the temperature created by the action of a limited quantity of water upon the carbide had a great deal to do with the result.

Result of the experiments

Other experiments were then made with mixtures of carbide and phosphide by plunging the mixture under the surface of several times its own volume of water, and it was then found that 25 per cent. of phosphide might in some cases be present without leading to spontaneous ignition, this of course being due to the cooling effect of the water present.

These experiments seemed to show that calcium carbide of ordinary commercial manufacture may be used without any danger from this cause for generating acetylene gas.

Time necessary to develop a dangerously high temperature

With regard to the likelihood of the temperature caused by the action of water on the carbide, experiments were made which showed that, when allowing water to drip at the rate of about 8 c. cm. per minute upon 227 grms. of carbide, it took always 16 to 17 minutes before sufficient heat was generated in the mass to reach 480°, the point necessary to ignite an explosive mixture; and it is manifest that long before this point has been reached an explosive mixture will have ceased to exist, the evolved acetylene having washed all air out of the generator, whilst with the form of generator in which carbide is dipped into water and then withdrawn by the rise of the gasholder, ten and a half minutes elapsed before the necessary temperature was arrived at.

Conclusions

It must be clearly borne in mind, however, that these experiments were made with a quantity of carbide far smaller than that employed in most generators, and it is just possible that in using charges of greater weight the necessary temperature might be reached before sufficient air was rinsed out of the generator to bring the mixture outside the explosive limits.

The prevention of danger from mixtures of air and gas in the generator

It should be perfectly easy, however, with generators in which there is considerable air space to devise an arrangement by which, after the generator has been charged and before the action is started, all air might be rinsed out of the generator by means of a small tube leading from the gas outlet of the holder, or if this were not possible a small auxiliary carbon dioxide apparatus on Kipp's principle might be arranged to rinse out the air by carbon dioxide, the small proportion of this gas so introduced and afterwards carried into the holder having no effect on the illuminating value of the acetylene itself.

As regards the safety of generators, there are many points which deserve attention.

Strength of the generator a factor in its safety

The strength of the generator plays an important part in the safety of the apparatus, as it is here that the only practical chance of explosion exists, and proper attention to its construction and power of resisting any accidental explosion that might take place must be an important factor in the safety of the installation.

Gerdes' experiments

Gerdes has investigated this point and has published a highly-interesting paper on the subject in *Glasers Annalen fur Gewerbe und Bauwesen*, 1898, vol. 43, 510. His experiments were carried out with the view of determining in what manner an explosion occurring in the generator may act on its walls, and in order to do this the generators were made with metal of a lighter gauge than ordinarily used and partly filled with water, the upper portion containing the mixture of

acetylene and air. The apparatus was placed in a pit

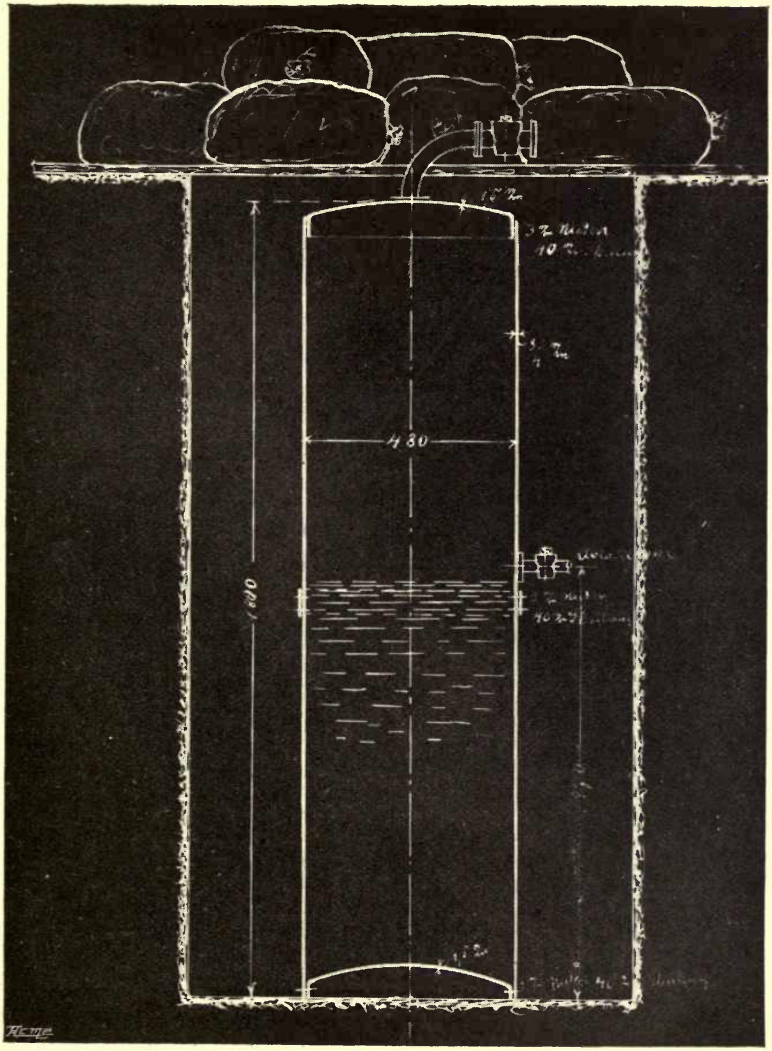


FIG. 136.

and the top of the pit was covered over with sand

bags, the contents of which weighed some hundreds of kilos.

In the first experiment the generator shot up to a

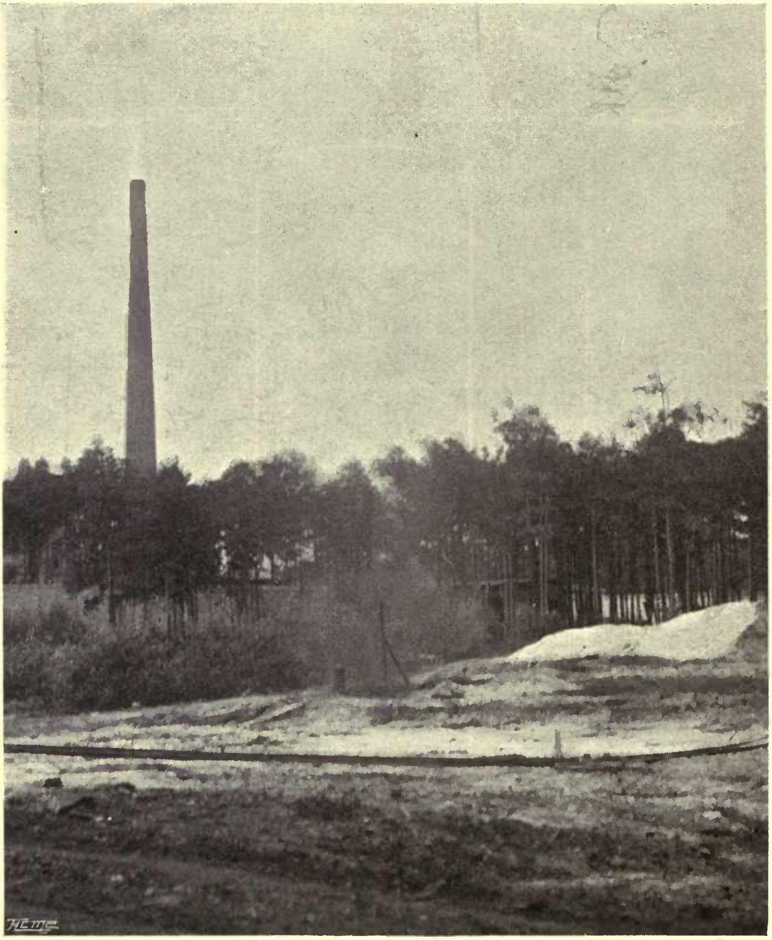


FIG. 137.

Result of the first experiment height of about six metres above the ground level, then turned over and fell upside down. The soil in the pit was thrown up by the explosion, and Figs. 137

and 138, taken from two different points, illustrate the effect of the explosion at two different stages.

Second trial In the second experiment the bottom of the generator was made stronger, and the explosion merely caused a bulging out of the part filled with water, as shown in Fig. 139.

Conclusions A third generator was treated in the same way, and

Fig. 138.

in this case it was burst open in the part filled with water in the manner shown in Fig. 140. These experiments show that it is not only the portions of the generator containing gas which are subjected to strain by the force of the explosion, but that the water in such a vessel transmits the pressure to the lower portions.

Construction of generators It is manifest that it is quite possible, by using good metal of sufficient thickness, to provide a generator

which, even should an explosion take place, would prevent any serious damage arising; but there are

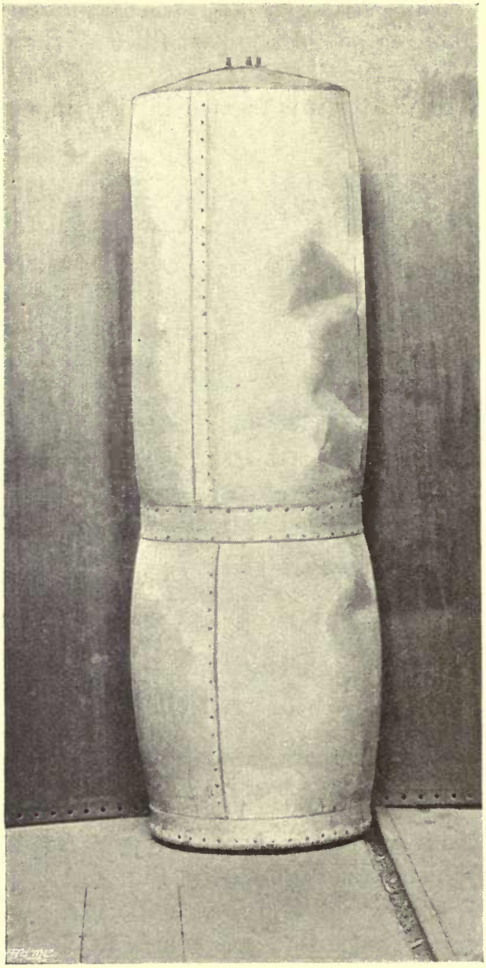


FIG. 139.

many points besides this which should be considered, and which, if properly carried out, would make anything like an explosion in the generator an impossibility.

Several accidents have happened through recharging generators at night, when a light was required for carrying on the work. With every generator there is always the probability that the opening of the carbide

Charging at night to be avoided

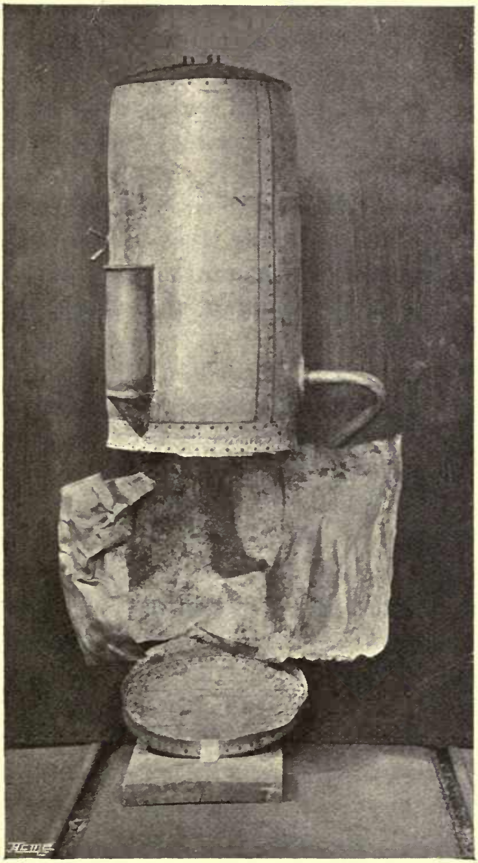


FIG. 140.

chamber to put in fresh material will allow a certain amount of acetylene to escape into the air, and a certain amount of air to find its way into the generator, and this should be minimised as much as possible.

Safety water seals *versus* cocks

A point which should be insisted upon in all installations is that, instead of having a cock between the holder and generator, there should be a water seal, which, when the generator is opened for recharging, will preclude the possibility of gas from the holder finding its way back through the generator: as if reliance be placed on a cock being turned off and on, there is always the chance that this will be forgotten by the unskilled labour on which one often relies for keeping the apparatus running, and should the cock be left open during charging a serious escape takes place. In order to prevent the need of recharging at night, the generator should be so designed as to provide a fair margin over the amount of gas likely to be used in the course of the evening, and should be filled up every day.

Low pressure an important point

It has already been pointed out that the increase of heating in a generator increases rapidly with pressure, and no generator should work at a pressure greater than is needed to put the gas into the holder, so that four to six inches ought to be the outside limit, whilst the holder pressure should be from two to three inches.

A store holder for gas advisable

Every one connected with the acetylene industry is now beginning to realise that for anything but the smallest installations a store holder of sufficient capacity to supply all the gas needed for an evening's consumption, and to leave sufficient holder room to provide for after-generation, is a necessity. The holder should be so arranged that, in the case of after-generation or over-production, any excess of gas should be allowed to escape without the increase of pressure necessary to blow the seal of the holder, as if this were relied on it would necessitate a regulator to be used between the holder and service, which is better avoided, as the holder itself forms by far the best pressure regulator.

Space for "after-production"

Blow-off valve

This may be attained either by having a small sealed blow-off on the inlet pipe just before the gas

is delivered into the holder, which will come into action at an inch higher pressure than is provided for in the holder itself, or by the very excellent arrangement due to Dr. N. Caro, which consists of a small elbow joint turned up at right angles, and attached to the lower edge of the gasholder, which slides in a recess provided for it in the holder tank, and which, when the holder has reached its upward limit, comes into a small funnel attached to a pipe leading outside the building, and so allowing an escape for the excess of gas.

Caro's holder relief valve

The holder should also be well supported and guided by either a central support or by properly-arranged columns, so that no jamming is possible. A trouble which is occasionally found owing to improper construction is that where the guide pillars are bolted to the rim of the holder tank; there is often a projection on which the weights counterpoising the holder tank catch and lodge for a few moments whilst descending, thus throwing an extra pressure on the gas, and causing the flames, if the gas is burning, to flare. If such a projection exists, the trouble can easily be overcome by fixing a small sheet metal guide over the joint.

Points to notice with the holder guides

Outside gasholders that are liable to exposure to frost should be filled with saturated salt solution, but the holder and tank must, under these conditions, be thickly coated with a good protective paint, and any loss from evaporation made up with ordinary water.

The question of the removal of the lime has already been dealt with, but it is well here again to point out that with the sludge cocks attached to many forms of apparatus, if the machine be allowed to stand for a couple of days before cleaning out, the lime settles into so dense a mass that the sludge cock becomes stopped, and on breaking a passage through it with a clearing rod the operator becomes exposed to a rush of lime sludge. It should be quite possible to design an

Troubles with sludge cocks

apparatus in which, after allowing twenty-four hours for settlement, the lime sludge could be removed by means of an endless screw in such a way that the working of the generator need not be stopped. In any case more attention should be paid to the arrangements for cleaning out the apparatus.

No soldering work allowable in generator construction

In constructing a generator, all parts should be made of sufficient strength to resist the effect of explosion, and no soldering should be allowed, everything being either rivetted or screwed, and where water seals are employed to close any part of the apparatus, they should be of such depth as to provide a good margin of resistance over and above the ordinary pressure existing in the apparatus, and must be protected from any chance of lime entering into them during the actions taking place in the generator.

No Mercury seals to be used

Mercury seals must not be used, as they rapidly become affected by the gas and its impurities. Gauge glasses so fixed as to offer any chance of breakage, or indiarubber tubing or other material liable to perishing, must on no account be employed in any part of the generator.

Attempts to slow down generation

In some forms of generator, attempts have been made to slow down in various ways the action of the carbide in the water by using saline solutions, and in some cases even a solution of sugar in the generator; but it is manifest that on a large scale any such devices would be too costly, and are practically not necessary. In some apparatus also, especially with those in which a chute leads the carbide down into the water, a layer of oil has been employed on the top of the water in the chute, with the intention of coating the carbide as it falls through the oil with enough of that substance to prevent the action of water upon it until it gets into the generating chamber itself, whilst sometimes the carbide is dipped into oil before dropping it into the generator, with the same effect in view. It is found, however, that the hydrocarbons so passed into

The use of oil in generators

the body of the generator give rise to a considerable amount of trouble, as the interior of the vessel gets coated with tar and oil, and the exit pipes are liable to choke owing to the sticky paste formed by the evolved products of the oil and lime dust.

In generators designed for what may be termed domestic use, in which sufficient acetylene has to be provided for the evening's consumption in from five to a hundred burners, all classes of apparatus are to be found, the requirements of the installation not being too large to allow of the water-to-carbide class being debarred owing to serious overheating, whilst still large enough to admit of the carbide-to-water generators being used with great success; but the moment either a larger or smaller apparatus is needed, the generators at once naturally divide themselves into the two main classes, the water to carbide type being the only one possible to employ in making small automatic apparatus to supply a single flame, whilst the carbide to water one is the only one it is found possible to use for lighting on a large scale, as where a village or small town has to be supplied from a central installation.

Natural division of generators into two classes for large and small installations

The success of an acetylene installation largely depends upon the way in which the fitting is done. In putting up an ordinary installation for a house a non-automatic generator should be employed, and a holder capable of containing sufficient gas to last the whole evening with the maximum number of lights burning. The generator and holder should both stand perfectly level upon a firm foundation, preferably of brick or concrete, and all pipes should have a slight fall back to the holder. The generator and holder, according to regulations, must be a short distance away from the house, and the building containing them must be well ventilated, and capable of being warmed by hot-water pipes in cold weather, so as to prevent freezing of the water in the holder

The fitting of Acetylene installations

The generator

and in the generator system. Where this is not practicable, the holder tank must be filled with a solution of brine, in which case all iron work, as before mentioned, must be carefully coated with a good protective paint.

The specific gravity of acetylene being 0·9 as against 0·4 of ordinary coal gas, the flow through the pipes is rather less; but inasmuch as less than one-fifth the volume of acetylene is required for each burner that is employed than for coal gas, this factor may be disregarded. A pipe of a given size may be taken as supplying three times as many burners as would be the case if coal gas were used. In ordinary installations the following sizes of pipes may be employed, and in no case should pipes smaller than ⅜ be used.

Size of pipes

⅜ inch pipe . . .	Up to 8 burners.
½ ,, ...	,, 15 ,,
¾ ,, . .	,, 60 ,,
1 ,, ...	,, 100 ,,
4 ,, ...	,, 2,000 ,,

Making joints

In house-fitting no composite pipe should be employed for acetylene, the best iron barrel only being used, and the joints should all be well-cut right and left-handed screw unions. No packing or paint must be used in making the joint, but the threads may be dusted with finely-ground plumbago. The reason for this is that tar, paint, and all the usual substances employed in making joints with coal gas are rapidly acted upon by the acetylene, becoming brittle and cracking, thus giving rise to leakage. The taps must be of the best brass, such as are used for water and steam work, with full taper plugs in deep barrels, so as to give plenty of grinding surface, the ordinary cheap brass fittings rapidly becoming leaky.

Taps and fittings

Soundness of joints

When the whole installation is complete, it should be carefully tested under a pressure of 15 inches of

mercury, and should not show a loss of more than 2 inches in twelve hours.

Starting an installation

In starting an installation, the holder should be filled with acetylene, and an indiarubber tube should be attached to the gas-fitting furthest removed from the holder, the burner being taken off for this purpose, and the end of the tube should be led outside a window. The gas from the holder should be run through the pipes until a test-tube blown full of the gas from the end of the indiarubber pipe burns quietly down in the tube when a light is applied to it; and where there are several branch services in the house, this should be repeated at the end of each. All the burners being then fixed in position, the gas may with safety be lighted.

Pressure

The pressure at which the gas is supplied to the house should not exceed $2\frac{1}{2}$ inches.

Cycle lamp and other small generators

The small form of generator finds its most successful adaptation in providing out-door lamps for cycles, motors, drive lamps, and signalling apparatus. For this purpose it is comparatively easy to design a generator sufficiently small to supply the gas as required to a single flame burner, and the great troubles of small generators—which are irregularity in the rate of generation, and serious after-generation—are of no serious moment, as any excess of gas can escape freely into the outer air without giving rise to the nuisance which would follow in a room or other enclosed space, and which has so seriously militated against the introduction of acetylene lamps for indoor use.

Acetylene cycle lamps

The acetylene cycle lamp has increased and multiplied to a very large extent during the last few years, and many and varied forms of apparatus have been devised for this purpose. The wonderful illuminating power of acetylene renders it capable of giving a clear view of a considerable distance of road ahead of the rider,

and although this is from a cyclist's point of view a certain advantage, it is not regarded with equal favour by pedestrians and the drivers of nervous horses, as the rapid passage of so brilliant a beam of light leaves the eye unable to discern surrounding objects for some few moments after the cyclist has passed.

Drawbacks to Acetylene cycle lamps

Moreover, the acetylene cycle lamp is distinctly more costly both in initial price and in maintenance than the oil lamp, and is also far heavier. The trouble and smell of recharging soon become a drawback when the novelty of the lamp has worn off, and when once the acetylene lamp has been charged, the whole of the carbide has to be used up, as it is impossible to stop the after-generation in so small a mass of material, and the only safe way is to allow the lamp to burn itself out, and it is manifest that this is a great drawback where the rider has to make a call of an hour or two. Unless the lamp is made heavy and clumsy, it does not contain a sufficiently large charge, the average lamp only lasting from 4 to 4½ hours, whilst in the winter months at least 6 hours' light may be wanted. The fact that the carbide also has to be used in all of them in a granulated condition means that it has been very largely decomposed during granulation, and as a result gives but a low yield of gas, whilst it is very difficult to find a construction in which the carbide and water do not rattle in the lamp with the vibration of the machine—a factor which often upsets the working of delicate valve arrangements intended to regulate the generation of the gas.

Conditions necessary in a good cycle lamp

A good acetylene cycle lamp should be able to satisfy the following conditions. The charge should be capable of being varied in amount, so that carbide either for a short period or for a maximum of six hours' generation can be put in; the lamps should not require regulation after having been once lighted, and if this should prove absolutely necessary, the

regulating tap should be in such a position that the rider can adjust it without dismounting. Provision should be made for keeping the carbide from shaking about in the lamp, and yet provide room for the lime formed during its decomposition. The gas should be capable of being completely extinguished without any great after production, and should in every case be filtered by passing through such material as silicate wool before being burnt, in order to guard against water vapour and lime dust being carried forward and choking the burner. Cycle lamps should not be constructed so as to work only with cartridges, as under many conditions it is impossible to get these, and the lamp is rendered useless.

Precautions to be taken in construction

The reflector should be of such a curve as to diffuse the greater part of the light immediately in front of the rider, whilst a small portion of the light should be concentrated into a beam to illuminate the road some distance ahead. This reflector should not be made of any metal liable to tarnish, and should be easily cleaned; and every care should be taken in the construction of the lamp to prevent back reflection of the light, either from the front of the lamp or from the ventilation air holes above the burner chamber, as nothing is more dazzling and blinding than an occasional glint from this source. The lens would be much improved if the upper half had its surface ground, an arrangement which would prevent the startling of horses, and the dazzling of passers-by, whilst the light would be still more concentrated upon the roadway. The burner should not be made of metal but of steatite, and, no matter whether a plain jet or flat flame, should be made on the air-injector plan; whilst provision should be made for cleaning out the burner in case of a stoppage by means of the cycle pump.

Cycle lamp reflectors

The lamp lens

The type of lamp in which a wick sucks or syphons

Troubles with capillary syphons

water to the carbide is not good, as the cotton soon gets choked with lime and loses its capillary powers. The charging and cleaning of the lamps should be made as simple and as easy as possible, the whole lamp being capable of being taken to pieces for cleaning, and the various parts should be made to gauge, so as to be interchangeable. Where fabrics such as cotton, muslin, or felt are used to act as a diffusing material for the water over the surface of the carbide, a surplus supply should always be kept, so that one set can be drying whilst a fresh set is in use.

Fig. 141.

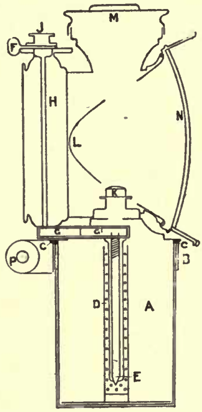


Fig. 142.

Condition of the Carbide used in cycle lamps

The carbide used in cycle lamps should be granulated down to a small and even size, as if lumps are used water is very apt to collect in cavities in the decomposed material, and by a sudden jerk of the machine is driven on to the carbide and causes a sudden rush of gas.

CLASS I. CYCLE LAMPS IN WHICH WATER DRIPS ON CARBIDE.

The Twentieth Century.—The carbide is placed in a cup A provided with a central perforated tube D, surrounded by a layer of muslin which diffuses the water to the carbide. This cup fits in an outer vessel, B, Fig. 142, which screws on to the base of the lamp, the joint being rendered gas-tight by the rubber ring C. A plate fitted with a spring keeps the carbide from shaking about in the carbide chamber. Water is admitted into D by a tube, having at the end a coned valve E. The flow of water is regulated from without the lamp by the thumb piece F, which actuates the rack-work G G^1 thus opening or closing the coned valve E. The water reservoir H is filled through the screw cap J. The gas is led to the burner K in the focus of the parabolic reflector L. The clip for attaching the lamp to the cycle fits on at P.

The "Twentieth Century" cycle lamp

Construction

The Excelsior.—A separate cup A, Fig. 143, with central perforated tube, holds the charge of carbide, and is fitted in an outer vessel D, which is attached to the body of the lamp by three clips G, a rubber ring C making the joint gas-tight. The top of the carbide cup is fitted with a perforated cover, over which a piece of linen is stretched and acts as a filter for the gas. The water chamber D is placed above the carbide chamber, and the rate of flow is

The "Excelsior"

Arrangement of water supply

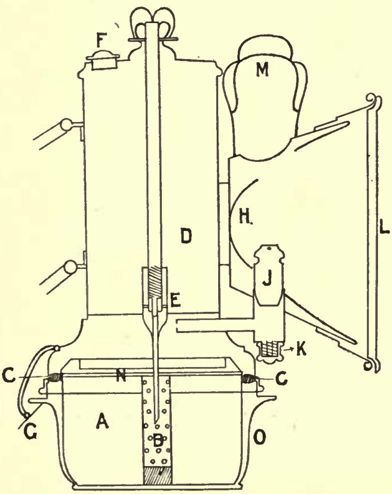


FIG. 143.

regulated by a coned valve E, worked from a thumb

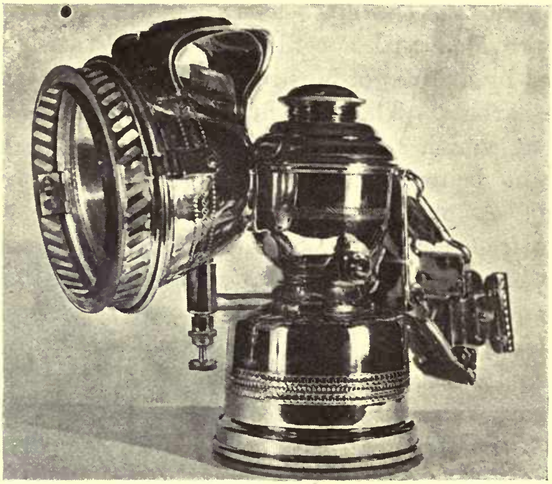


Fig. 144.

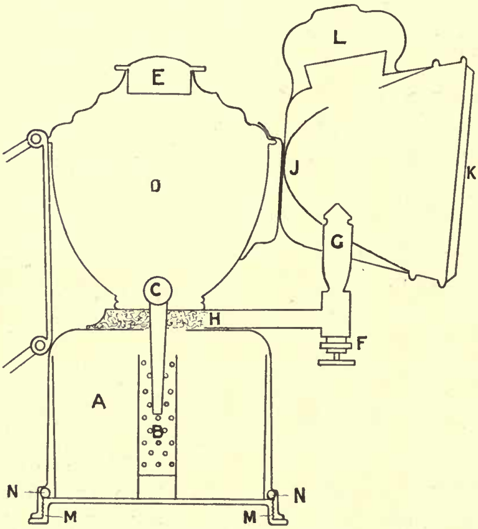


Fig. 145.

piece at the top of the lamp. The gas burner J enters

the burner chamber, which is fitted to the side of the lamp in the focus of the reflector H. A screw thread K below the burner, and provided with a cap, allows of a cycle pump being attached for cleaning the burner.

The "Windmiller" cycle lamp

The Windmiller (Figs. 144, 145).—The carbide cup A fits into the base of the lamp, and is rendered gas-tight by the base plate M, which screws on to the body of the lamp against the rubber ring N. Water drips from the reservoir D above, into the perforated tube B, and the rate of flow is regulated by the side tap and valve C. A chamber H, filled with a porous material H, acts as a gas filter. The burner is provided with a screw F, to which a pump can be attached for cleaning the burner, and with an arrangement for adjusting the size of the flame or shutting off the gas supply altogether.

The "Phenomenon"

The Phenomenon (Figs. 146, 147).—In this lamp also water drips on to carbide contained in the detachable

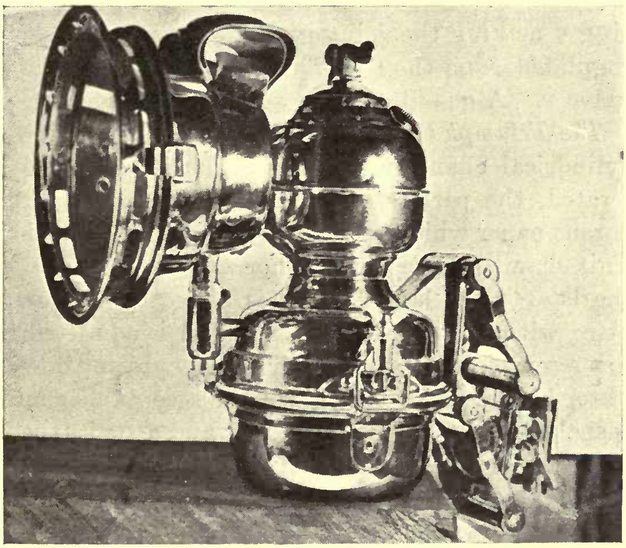


FIG. 146.

cup A enclosed in the chamber D, which is clamped to the body of the lamp by three screw clamps C, a rubber

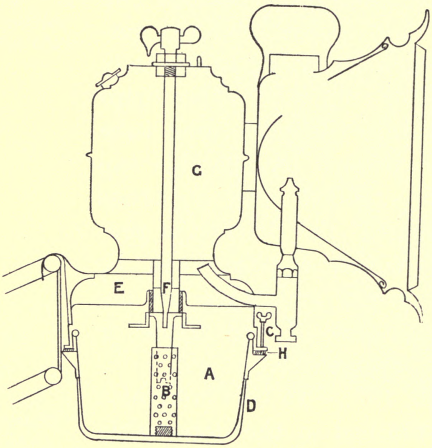


FIG. 147.

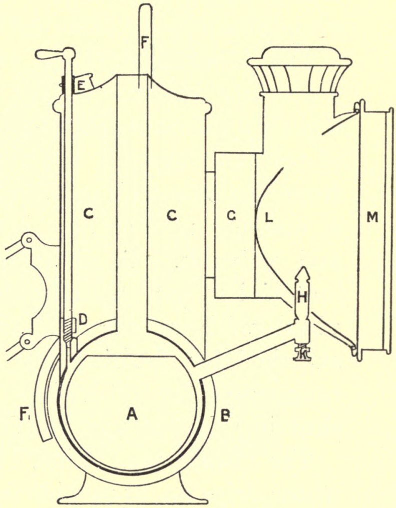


FIG. 148.

ring H making the joint good. The water supply is regulated from the top of the reservoir G by the cone valve F. A gas-filtering chamber is provided at E.

The "Triumph"

The Triumph (Fig. 148).—The carbide is placed in a cylindrical chamber A, the bottom of which is perforated, the perforations being covered by a piece of porous paper which requires renewing for each charge. This chamber slides into a horizontal receptacle B at the base of the lamp, which is closed by a screw cap fitted with a rubber washer. Water is admitted from the reservoir C by a coned valve D, which allows the water to flow down the side of the receptable B until it is sucked up by the porous paper and attacks the carbide. Safety vents, to avoid excessive pressure of gas, are provided at F and F^1. A novel arrangement is fitted at G, which is a chamber at the back of the burner chamber, and containing a roll of explosive

caps. On turning a button outside the lamp, a hammer is lifted and falls on one of these caps, causing a flame which lights the gas at the burner H.

The "Majestic" cycle lamp

The Majestic (Figs. 149, 150).—The carbide chamber A, fitted with central perforated tube A^1, is attached to the lamp by a strong wire clamp, which passes from

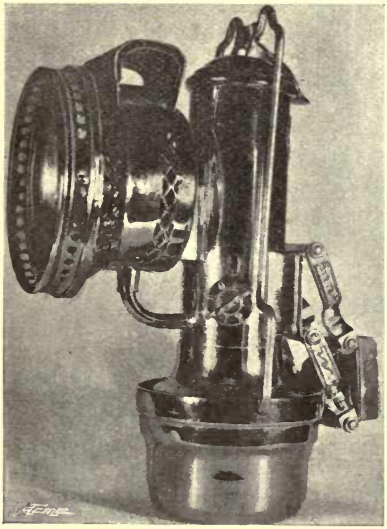


FIG. 149.

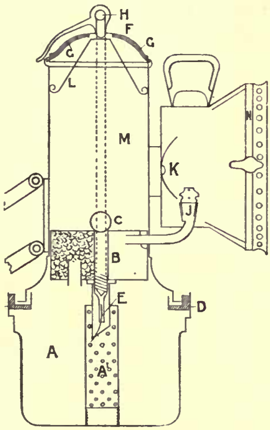


FIG. 150.

the carbide chamber to the top of the lamp, where a lever arm draws the carbide chamber tight against the rubber ring D. The water supplied from M is regulated by the coned valve C, worked from the side of the lamp. The cap F of the water chamber lifts off, and has a rubber washer G to prevent the escape of water, whilst the springs L serve to keep it in position. The gas has to pass through the filtering chamber B before reaching the burner J.

The "Leuchtkugel"

The Leuchtkugel (Figs. 151, 152).—In this lamp the carbide chamber *f* and perforated diffusing tube are separate, the latter passing up through a hole in the

cup, and the top of the tube is provided with a screw thread *g*, engaging with a screw on the water drip,

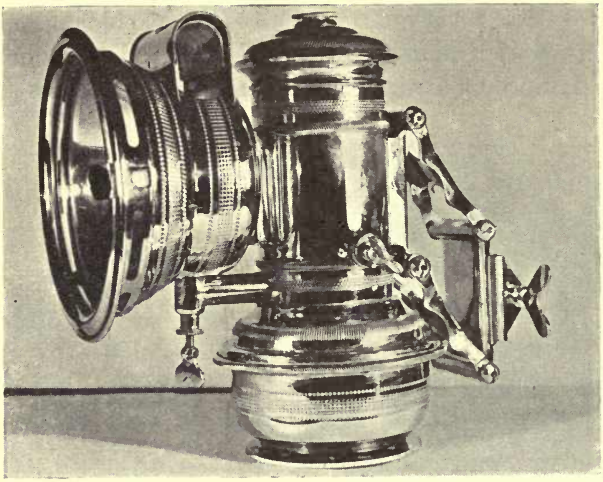


FIG. 151.

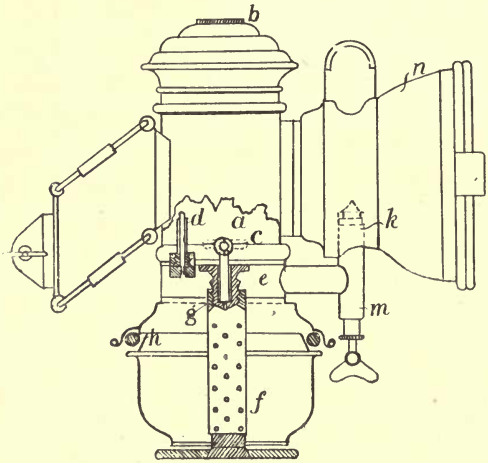


FIG. 152.

the lower end being fitted with a flange and rubber washer. By this means the carbide cup is drawn up

against the bottom of the lamp, the joints being rendered gas-tight by the rubber ring *h* and the washer of the tube. The water-regulating tap, at the side of the lamp *c*, allows the water to drip from the water reservoir *a* into the diffusing tube.

The "Bundy"

The Bundy (Figs. 153, 154).—An outer chamber *r* screwing into the lamp carries the carbide, which is made up in cartridge form *s*. The cartridge is pierced by a central tube *j*, with two lateral openings which allow the water to attack the carbide. The water is admitted to the central tube from the water reservoir *m* by means of the coned valve *f*, which is actuated by a small handle *n* at the side of the lamp. The gas passes through a filtering plug *d* to the burner *a*. The burner chamber fits over the top

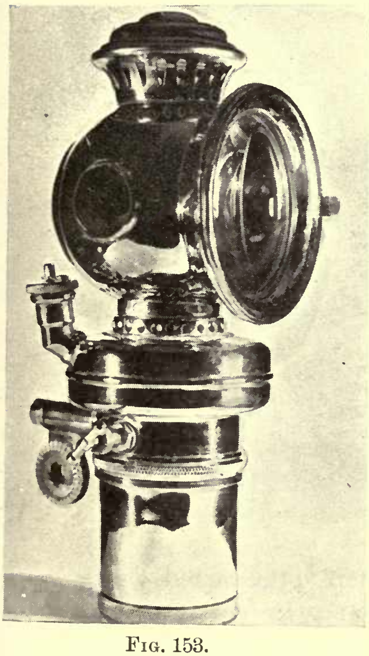


Fig. 153.

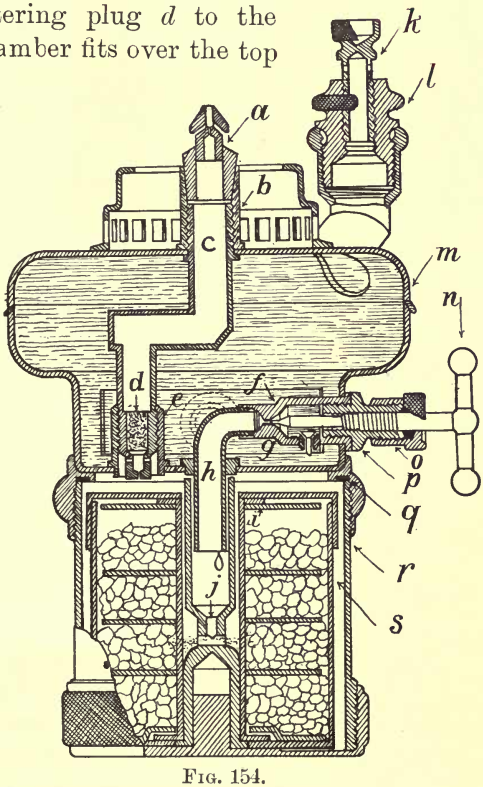


Fig. 154.

of the lamp by means of a bayonet joint. The water is poured into the reservoir through *k*.

The "Cetolite"

The Cetolite (Figs. 155, 156).—The water reservoir

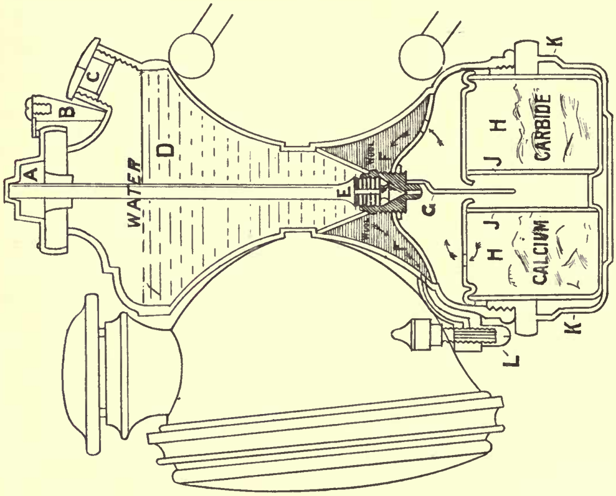


Fig. 156.

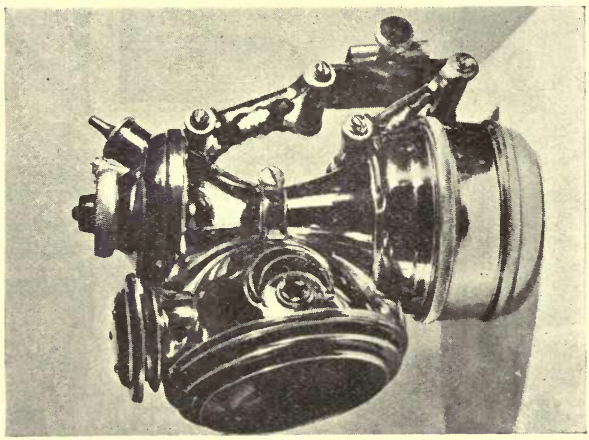


Fig. 155.

forms the upper part of the lamp D, the carbide being placed in a receptacle K, which screws on to the lamp below. Water is supplied to the carbide by a coned

valve E, worked by a button A on the top of the lamp. The gas passes through a chamber filled with filtering material F before entering the burner, which is placed in a parabolic chamber at the side of the water reservoir.

The "Acetylator"

The Acetylator (Figs. 157, 158).—The vessel containing the carbide screws on to the lamp at the bottom, and water is admitted to the side of this vessel by a

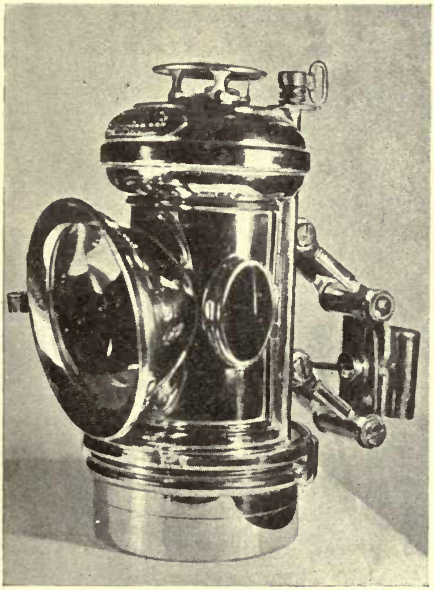


FIG. 157.

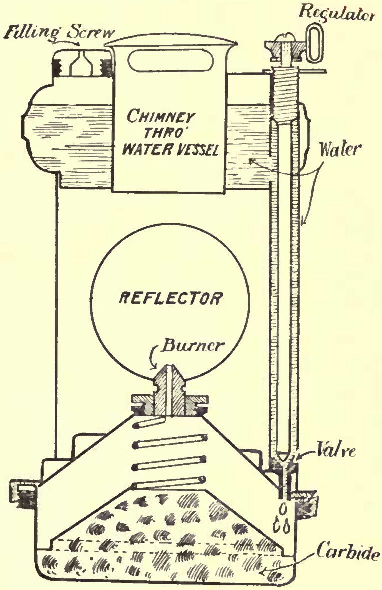


FIG. 158.

tube furnished with a coned valve actuated from the top of the lamp, leading from the water reservoir above. The centre portion of the lamp forms the burner chamber, and the products of combustion pass through a chimney, which is fixed in the centre of the water supply.

The 'Solitaire'

The Solitaire (Figs. 159, 160).—The water reservoir is situated at the back of the burner chamber and on top of

the portion which contains the carbide. The carbide is placed in a metal cup fitting in the lower part of the lamp, and is pressed up against a wire gauze by means of a spring. The base of the lamp is closed by a screw

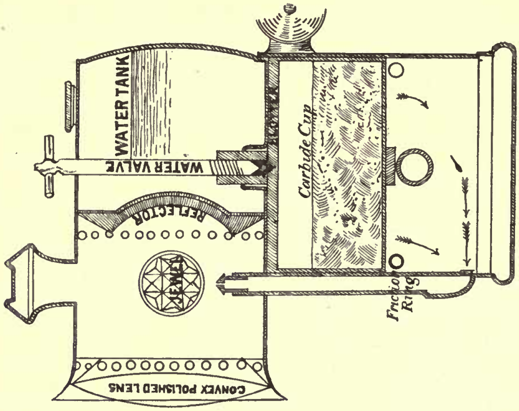


Fig. 160.

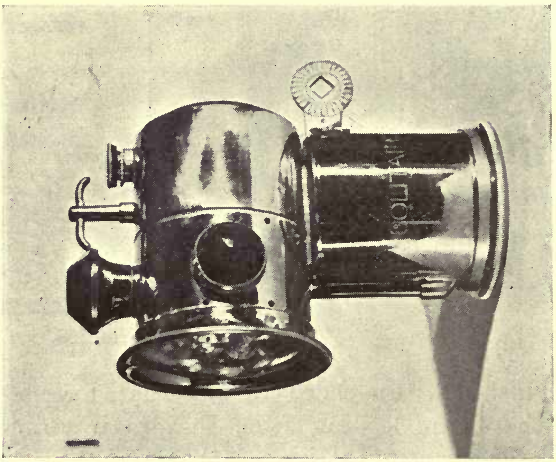


Fig. 159.

cap. Water drips from the water tank on to the wire gauze, and is diffused over the carbide by a piece of blotting paper placed on top of the carbide, the rate of flow being regulated by a coned valve worked from the

top of the lamp. The gas as it is made passes through the carbide, which frees it from water vapour, and is led by a tube from the base of the lamp to the burner.

Class 2. Water Rises to Carbide.

The "Veritas"

The Veritas (Figs. 161, 162).—This lamp is automatic in its working, and requires no regulation of the water supply after the water has once been turned on. The carbide is contained in a cup G, which fits into an outer vessel surrounded by the water reservoir H. The

Fig. 161.

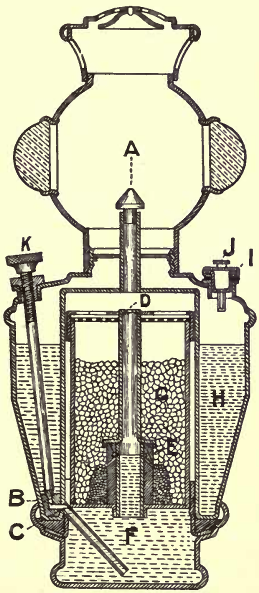


Fig. 162.

water valve B allows the water to fill up the chamber F, which acts as a store for any excess of gas, and rise to the carbide by the diffusing tube E. The upper portion of this tube leads the gas to the burner A at the top of the lamp, the burner chamber being secured to the body of the lamp by a bayonet joint.

The "Acetylette"

The Acetylette (Figs. 163, 164).—This lamp consists of an ordinary lamp body with lens, etc., but the bottom of the lamp forms a water chamber. It is fitted with spring clips, which hold the "gas candle" in position.

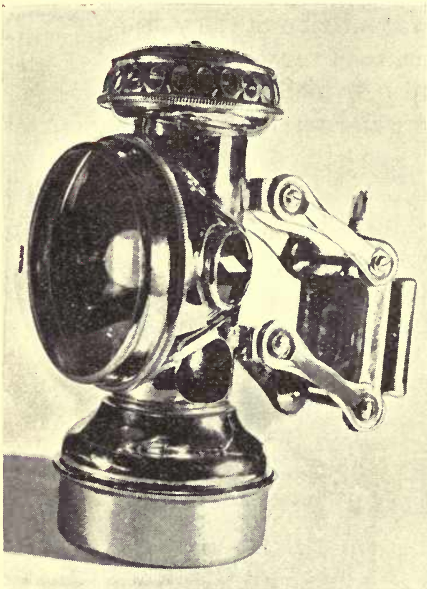


FIG. 163.

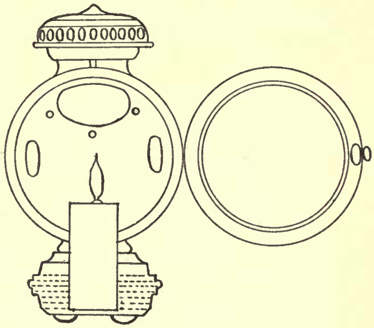


FIG. 164.

The "gas candle" is a cartridge of carbide, the top of the cartridge being pierced with a minute hole to form a burner, whilst the lower end has a larger hole, through which the water passes to the carbide after traversing a plug of porous material.

CLASS 3. WATER SYPHONS ON TO CARBIDE.

The "Yahr"

The Yahr (Figs. 165, 166).—The carbide chamber A is surrounded or jacketed by the water vessel B, the top being closed by a hinged lid, which is clamped against a rubber ring F by a screw and nut. Through the centre

of the carbide chamber is a tube, opening at the bottom in the water vessel, and through it pass strands of fibrous material C, such as worsted, the free ends of which fall on a disc of fine wire gauze M on the top of the carbide. A spring D keeps the carbide from

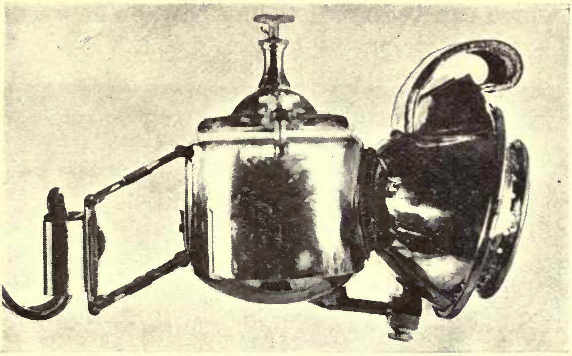


FIG. 165.

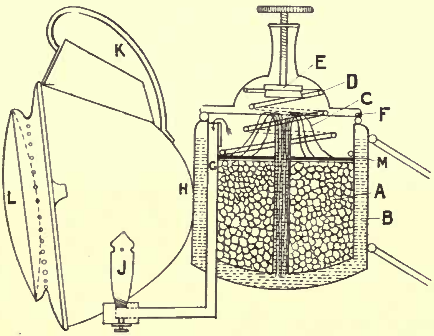


FIG. 166.

Construction and working

shaking about, whilst the rubber-tipped screw plug E can be shut down on to the top of the water pipe. The gas is led from the top of the carbide chamber by the pipe G to the burner J, which is in the focus of a reflector H in a chamber at the side of the lamp.

The "Scharlach"

The Scharlach (Figs. 167, 168).—Water drips from a reservoir placed above the carbide chamber into a per-

forated tube, which is fitted to a flange plate, and is separate from the carbide receptacle. This receptacle is secured to the lamp by three clamps, the joint being made gas-tight by a rubber ring. The water flow is regulated in the large size lamps by a valve, which is worked from the side of the lamp by means of a lever arm, which can be moved to any position on a scale by

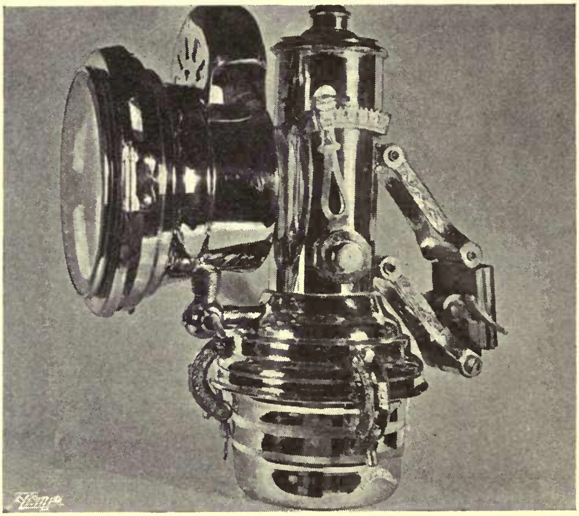


Fig. 167.

Arrangements for working and cleaning burner

means of a rack and pinion. A filter chamber for freeing the gas from dust, etc., is provided. The burner can be cleaned by a novel method. Instead of the cycle pump being attached to a screw thread below the burner, a cap is provided which screws over the burner and to which the pump can be attached. In this way the air blast is directed downwards, obviating all danger of blowing out the burner tip, and at the same time removing all dust, which is blown through a small hole in the gas pipe, this hole being normally closed by the tap seen at the angle of

the pipe. The water reservoir and burner chamber are insulated from conduction of heat from the

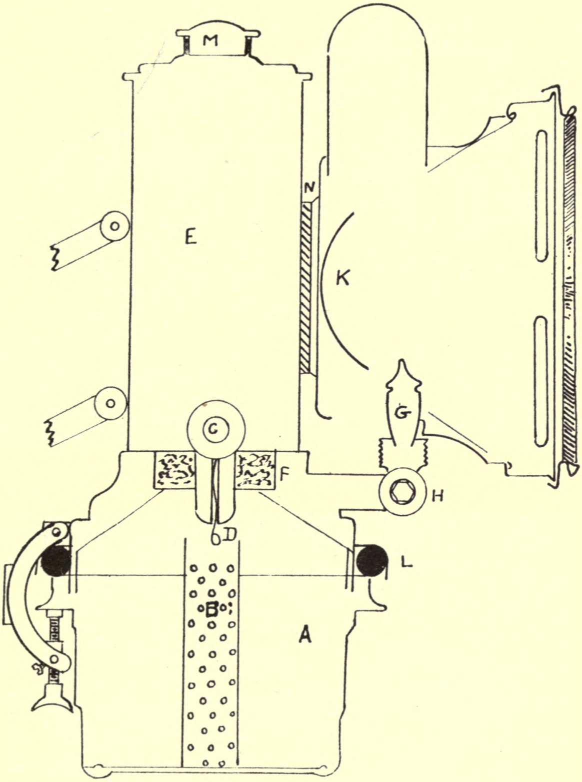


FIG. 168.

carbide chamber by means of washers of vulcanised fibre.

The Fritz (Figs. 169, 170).—A tin vessel containing the carbide is placed in the base of the lamp, which is then closed by the hinged base plate and fastened by three screw clamps. The carbide vessel is perforated at the top and bottom to allow the water to reach the carbide. Water flows from a reservoir on the top of

The "Fritz" cycle lamp

the lamp, the rate of flow being governed by a milled head at the top, which actuates a coned valve.

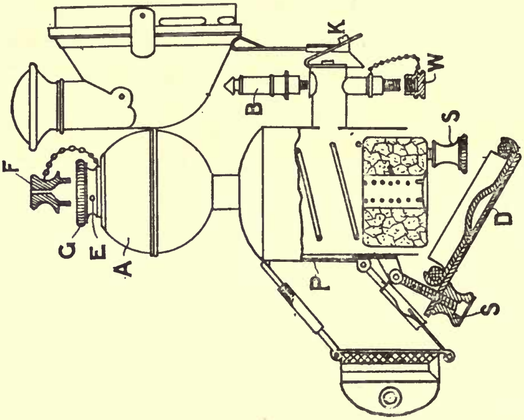


FIG. 170.

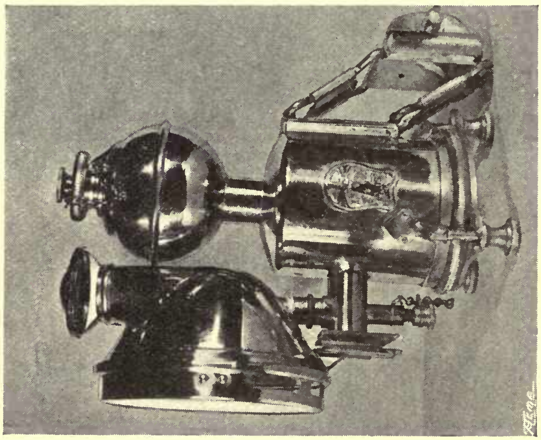


FIG. 169.

The "Hutton" lamp

In the *Hutton* cycle lamp, Fig. 171, the generator is separate from the lamp proper, and is clipped on to the diagonal tube of the machine, a small rubber tube conducting the gas to the lamp on the lamp bracket. The

FIG. 171.

generator consists of a water-dripping arrangement, being divided into two compartments, the upper containing the water and the lower the carbide.

Another form of outdoor lamp for which the use of acetylene is permissible is the carriage or motor car lantern, as here also the after- and super-generation of gas can find vent in the open air.

Carriage lamps

In order to encourage the adoption of acetylene for this class of lighting, the carriage lamp has to be made of the same size and interchangeable with the ordinary candle lamp, and this restricts the size of the generator to as small or smaller dimensions than the cycle generator; whilst it is better to have the generator removable from the head of the lantern, so as to be able to replace it by a candle in the event of the carbide running out.

General construction

A description of one or two forms of these lamps will suffice to indicate the general arrangement.

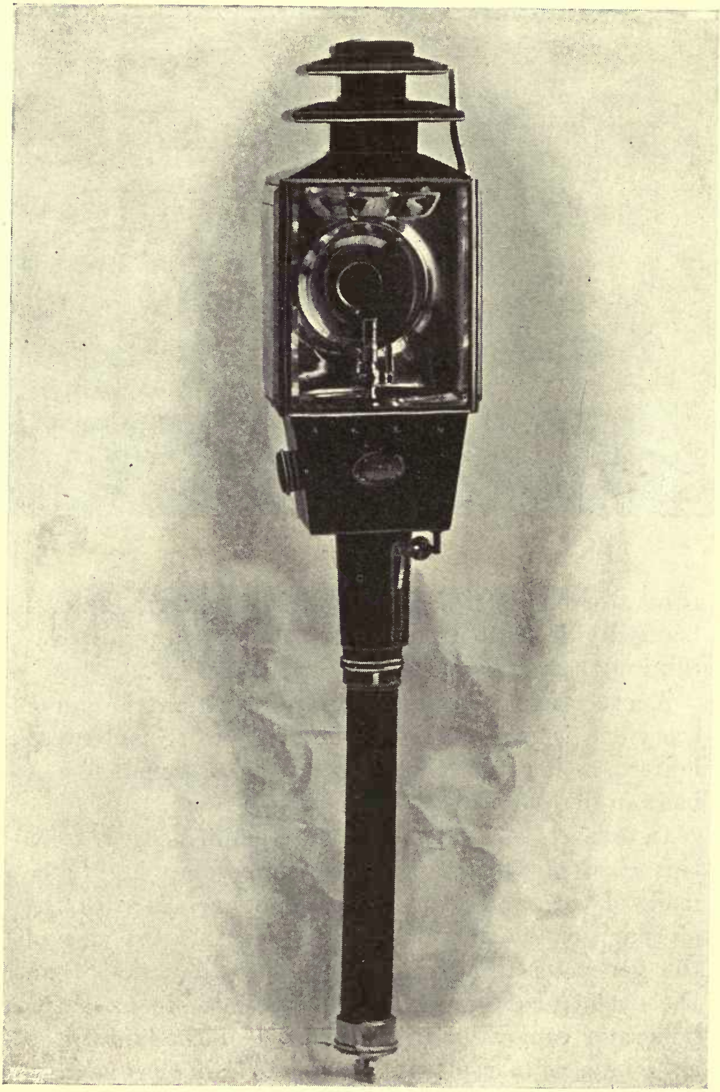


FIG. 172.—AN ACETYLENE CARRIAGE LAMP

The A.C.A.G. Carriage Lamp (Fig. 173).—The carbide is placed in a metal cylinder, open at the top and closed at the bottom, sliding friction-tight into another cylinder open at the bottom and carrying on the top the burner pipe. An outer case enclosing the two "A.C.A.G." carriage lamp

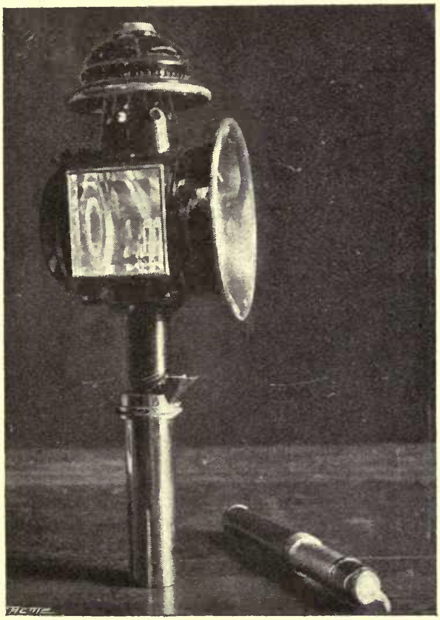


FIG. 173.

cylinders screws on to the body of the lamp. Water is placed in the outer vessel, and finds its way to the carbide by passing between the two cylinders, the carbide cylinder having a row of perforations at one side to allow the water to enter.

The Scharlach Carriage Lamp (Fig. 174).—This lamp works on the same principle as the cycle lamp made by this firm. Water drips from a reservoir below the burner of the lamp into a perforated tube placed in the centre of the carbide chamber. The rate of The "Scharlach" carriage lamp

flow is regulated by a lever arm, which works a coned valve, moving over a scale on the top of the water reservoir.

Acetylene lamps for signalling

There are two applications of the acetylene lamp which, although not offering a very large commercial field, are yet of very considerable importance. The power of signalling by night is one of the greatest

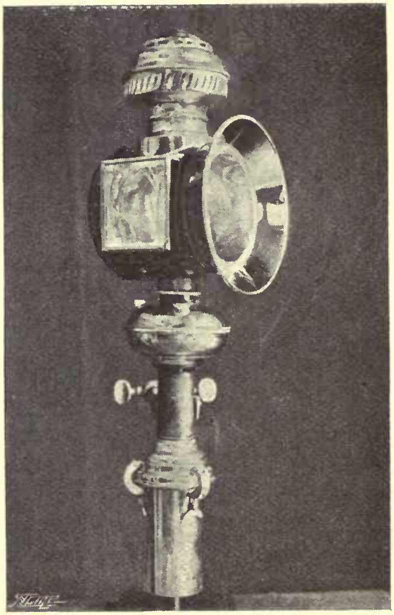


FIG. 174.

moment to military forces in the field, and for this purpose acetylene offers marked advantages over any other available source of light, as the apparatus for the purpose is portable and not too heavy, whilst the beam produced is powerful and penetrative. An excellent apparatus for this purpose is shown in Fig. 175.

A second application is the production of a portable

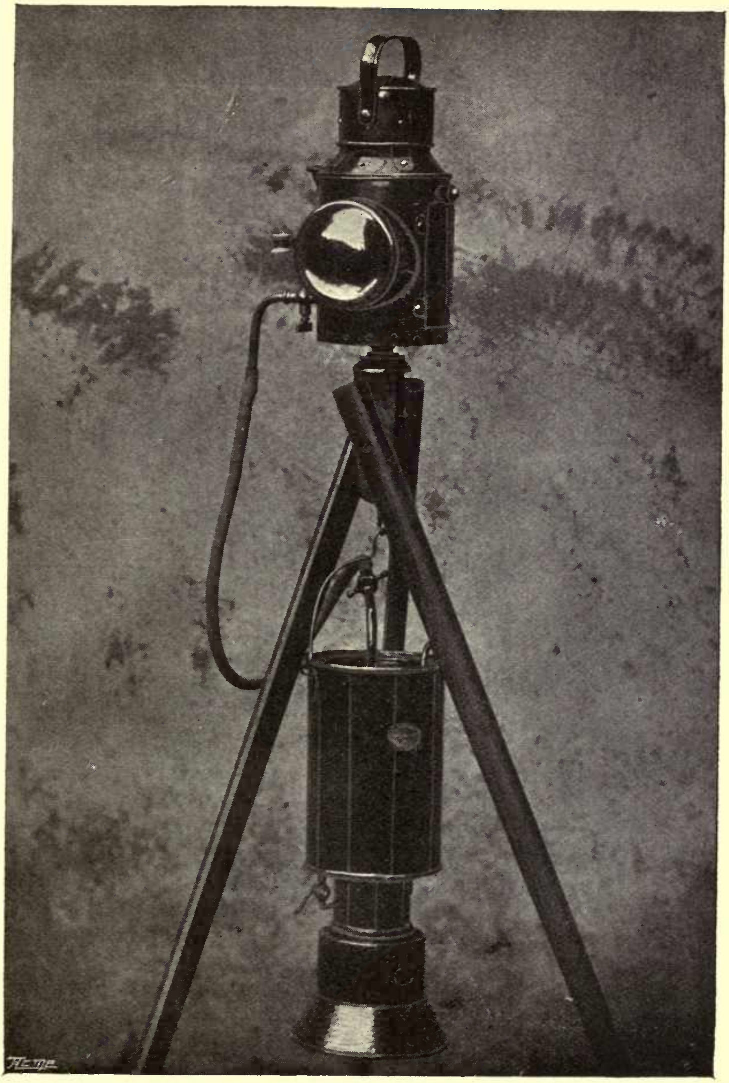


FIG. 175.

Acetylene search-lights

searchlight for use at fires, where the working of the men is often hampered by inability to see owing to steam and smoke, and where a powerful beam of light would be of the greatest value. A cluster of from

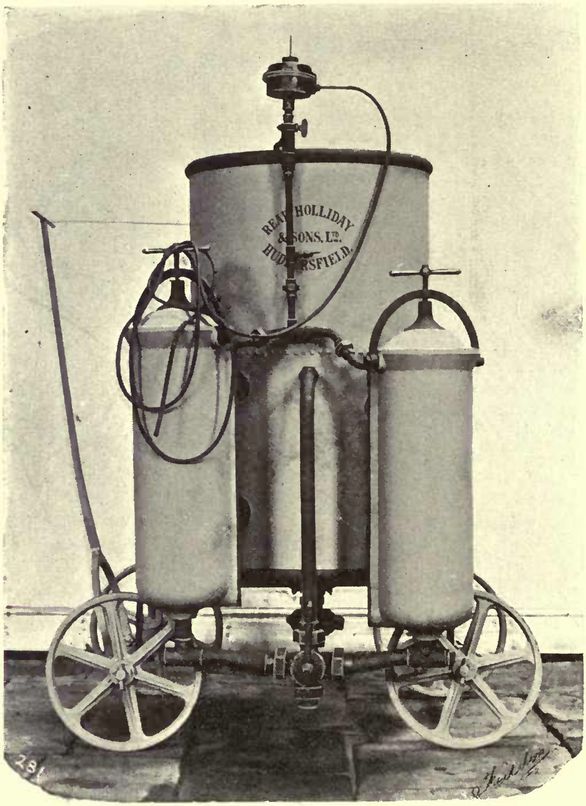


Fig. 176.

five to ten lights, arranged in a large lantern head with a good reflector, would answer admirably for this purpose, whilst a generator mounted on wheels, such as is shown in Fig. 176, would easily supply the

Portable generators

necessary gas. Such portable generators are already

being found of great service for wharf lighting and other purposes of the same kind.

Table lamps, and the troubles that militate against them

Ever since the introduction of acetylene on a commercial scale attempts have been made to construct a table lamp, which should develop the gas as it was required and give no smell; but all have so far failed to produce a lamp that can be really looked upon as fitted for the purpose. They are as a rule clumsy and ugly in construction, whilst the troubles of over- and after-generation invariably give rise to smell and a feeling of uneasiness on the part of the user.

Many of them work at dangerously high pressures, and it must be borne in mind that all of them would be classed as acetylene generators, and would come under such stringent regulations as to prevent their extended use.

Escape of surplus gas

The trouble of the escape of any surplus gas into the air of the room in which the lamp is being used is undoubtedly the greatest trouble with this class of apparatus; and the suggestion made by Lorimer of having a chamber in the upper portion of the lamp filled with acetone, or material saturated with this solvent, for the absorption of surplus gas, is undoubtedly a promising direction in which to look for a solution of this trouble.

CHAPTER VIII

THE IMPURITIES OF COMMERCIAL ACETYLENE, AND THE PROCESSES ADOPTED FOR THEIR REMOVAL.

The causes which lead to impurity in crude Acetylene

THE purity of commercial acetylene gas primarily depends upon the purity of the carbide from which it is formed; and as long as it is commercially impossible to use absolutely pure calcium oxide and carbon, so long will there be always present in this material calcium phosphide, calcium cyanide, aluminium sulphide, and magnesium nitride, which, on the decomposition of the mass by water, will yield a gaseous and unwelcome addition to the acetylene of phosphuretted hydrogen, sulphuretted hydrogen, and ammonia.

Phosphuretted Hydrogen, and the result of its presence in Acetylene on the air of a room

Phosphuretted hydrogen, when burning in the acetylene flame, gives rise to phosphorus pentoxide, which escapes into the atmosphere in the form of white fumes; and although the quantity is so minute that it is invisible as it leaves the acetylene flame, still, when mingled in quantity with the air of an ill-ventilated room, it is the primary cause of the production of a light haze, which, ever since the introduction of acetylene for illuminating purposes, has been recognised as a serious inconvenience in connection with it.

The influence of water vapour in aiding the formation of haze

The atmosphere of a warm room always contains large quantities of water vapour, derived both from the respiration of the occupants and from the products of the combustion of the illuminating flame; and under

ordinary conditions this moisture remains suspended in the atmosphere in an invisible state, but as soon as traces of phosphorus pentoxide escape into it, this substance, having a marvellous affinity for water, causes a condensation of a portion of the water vapour, and converts it into phosphoric acid, so that a very small trace of phosphuretted hydrogen in the gas itself gives rise to an amount of haze totally out of proportion to the actual phosphorus present. Where there is a considerable quantity of acetylene consumed, and no proper method of changing the air of the room, this haze will often be found, and it is undoubtedly injurious to health.

Haze due to the condensation of water vapour by Phosphorus Pentoxide

The sulphuretted hydrogen formed by the action of water on the aluminium sulphide in the gas is objectionable, not so much because it renders the smell of the acetylene offensive, a function which may be looked upon as a safeguard, but because in its combustion in the acetylene flame it forms water vapour and sulphur dioxide, which latter, in ill-ventilated apartments, will absorb oxygen and moisture from the air, and will in this way become converted into minute traces of sulphuric acid, which, concentrating themselves upon any cold surface in the room, give rise to corrosion of metals, and in time to destruction of the binding of books, although the effect is but small upon such fabrics as have not the power of absorbing moisture or condensing it from the atmosphere.

The presence of Sulphuretted Hydrogen in crude Acetylene

The products of combustion of Sulphuretted Hydrogen and their action in the atmosphere

The chief objection to ammonia, the third impurity present in the acetylene, is that it leads to rapid action upon the brass gas fittings, and is also an important factor in producing explosive compounds of acetylene with metals, although the experiments made by Gerdes have shown that this is not a very real danger.

The action of Ammonia as an impurity

Products of combustion of Ammonia

The ammonia, on burning in the flame, also forms

water vapour and nitrous acid; and when acetylene is burnt for some time in an enclosed space ammonium nitrite can be detected, and salts of this character may add to the formation of the "haze."

The importance of purification

It is quite clear that acetylene, if it is to be used on a large scale as a domestic illuminant, must undergo such processes of purification as will render it harmless and innocuous to health and property; and the sooner it is recognised as absolutely essential to purify acetylene before consuming it, the sooner will the gas acquire its deserved mead of popularity.

Before discussing the methods of purification which it is possible to adopt, it will be well to see to what extent these impurities exist and their nature.

The impurities of crude Acetylene, and the extent to which they are present

Lundstroem[1] has studied this question, and gives the impurities and their limits as being:—

	Minimum.	Maximum.
Sulphuretted hydrogen	0·00	1·34
Ammonia	0·06	2·80
Phosphuretted hydrogen	0·03	1·70
Siliciuretted hydrogen	0·00	0·80
Arseniuretted hydrogen	0·00	0·004
Carbon monoxide	0·00	1·48
Hydrogen	0·07	0·27
Nitrogen	0·20	2·91
Oxygen	0·55	1·18

Hydrocarbons other than Acetylene present in the gas

and to these must be added the vapour of benzene and other hydrocarbons of the saturated and unsaturated series, formed by the action of heat on the acetylene during the process of generation.

It must be borne in mind that the calcium carbide made during the past two years has been far purer than the samples prepared in the early days of the industry, and that this has a marked influence on the purity of the gas prepared from it.

[1] *Zeitsch. Calc. Acet.*, 3, 23.

This is more noticeable in the case of phosphuretted hydrogen than with the other impurities, as this was early recognised to be the cause of the troublesome haze incidental to the use of impure gas, and the carbide manufacturers at once turned their attention to obtaining lime and carbon as free from phosphorus compounds as possible.

Improvement in the purity of the Calcium Carbide

In 1896 the author had occasion to investigate the percentage of phosphuretted hydrogen present in acetylene generated from the carbide then on the market. Samples of ordinary commercial carbide were purchased from various dealers, and care was taken that the English, American, and Continental carbide should be all represented.

The percentage of Phosphuretted Hydrogen present in Acetylene in 1896

The samples were numbered one to twelve, and an equal weight of each being employed, acetylene was generated from them by the action of water. The phosphuretted hydrogen in the gas was then determined with the following results:—

Results of experiments

Number of sample.	Percentage of phosphuretted hydrogen.	Number of sample.	Percentage of phosphuretted hydrogen.
1	0·43	7	0·72
2	0·91	8	trace
3	2·30	9	0·51
4	0·58	10	0·02
5	0·62	11	0·77
6	0·32	12	0·80

Average from all samples, 0·65 per cent.

From this it is seen that prior to 1897 it was the exception, rather than the rule, to find less than a half per cent. of phosphuretted hydrogen in the crude acetylene, and with this proportion haze was invariably formed in a small room.

During 1899, however, twelve samples of commercial

The Phosphuretted Hydrogen present in Acetylene from Commercial Carbide in 1899

carbide of fairly international character, analysed in the author's laboratory, gave :—

Number of sample.	Sulphuretted hydrogen.	Phosphuretted hydrogen.	Number of sample.	Sulphuretted hydrogen.	Phosphuretted hydrogen.
1	0·166	0·17	7	0·14	0·10
2	0·16	0·07	8	0·11	0·13
3	0·12	0·15	9	0·10	0·02
4	0·41	0·04	10	0·06	0·04
5	0·10	0·14	11	0·09	0·038
6	0·12	0·05	12	0·09	0·02

showing clearly the remarkable advance in purity of the carbide made during the past two years.

The other impurities are of far less consequence in the gas, and the following analyses made by Wolff of acetylene generated from American, German, and Swiss carbides, as at present made, give a very fair idea of the results obtained in acetylene generated without undue heating from good samples of carbide :—

Analyses of crude Acetylene

	American.	German.	Swiss.
Phosphuretted hydrogen .	0·05	0·03	0·03
Sulphuretted hydrogen .	0·08	0·07	0·10
Ammonia	0·08	0·07	0·11
Hydrogen	0·09	0·07	0·16
Nitrogen	0·42	0·20	0·34
Oxygen	0·87	0·55	0·63
Acetylene	98·41	99·01	98·63
	100·00	100·00	100·00

Willgerodt proposes Bromine water to remove Phosphuretted Hydrogen

It was Willgerodt,[1] in 1895, who first pointed out the presence of phosphuretted hydrogen in commercial acetylene, and showed that it could be removed by slowly passing the gas through three wash bottles

[1] *Berl. Ber.*, 28, 2,107.

containing bromine water, which oxidised the phosphuretted hydrogen into phosphoric acid.

The source of the Phosphuretted Hydrogen in the crude gas

The presence of this impurity having been clearly demonstrated, the theory of the cause of its formation most generally accepted was that the phosphorus compounds in the lime became reduced, with the result that calcium phosphide was formed, and this, decomposing on contact with water, yielded phosphuretted hydrogen.

Moissan's researches on Calcium Phosphide

Moissan[1] has studied the preparation and properties of crystallised calcium phosphide as formed in the electric furnace, and made this compound by fusing together 310 parts by weight of tricalcium phosphate with 96 parts by weight of lamp black, and found that the crystalline body formed, $Ca_3 P_2$, if sufficiently heated in the furnace, was only slowly acted upon by water, and yielded phosphuretted hydrogen that was not spontaneously inflammable. He also found that all the phosphorus is not liberated in the form of hydride, and that probably a somewhat complex reaction takes place.

The action of water on Calcium Phosphide made in the electric furnace

Caro's investigations on Phosphides

Caro[2] has also investigated this point, and says: "Phosphorus occurs as calcium phosphate in the lime and coke used. The phosphate is reduced in the electric furnace into phosphide by incomplete reduction, as pointed out by Moissan. An excess of coke reduces this, and the phosphorus distills off, as in the electric process, for the preparation of phosphorus from calcium phosphate devised by Frank and Hilpert. This property of the calcium phosphide enables us to make a carbide poor in this substance, if the product obtained is well fused with an excess of carbon.

Liquid and gaseous Phosphuretted Hydrogen

"The calcium phosphide produced is decomposed by water with formation of hydrides of phosphorus. It cannot be decided with accuracy if this calcic phosphide is a derivative of gaseous ($H_3 P$) or liquid ($H_4 P_2$)

[1] *Compt. Rendu*, 1899, 128, 787. [2] *Zeitsch. Calc. Acet.*, 3, 97.

phosphuretted hydrogen. I do not think that the phosphide corresponding to $H_4 P_2$ occurs in the carbide, because I never succeeded in finding this compound in molten carbide. The phosphide obtained in the ordinary way always gives spontaneously inflammable phosphuretted hydrogen, but the calcium phosphide obtained by the method employed by Moissan in the electric furnace gives nearly always the non-spontaneously inflammable phosphuretted hydrogen, H_3P. I also succeeded in proving that the calcium phosphide giving H_4P_2 is decomposed in the electric furnace, and yields a phosphide which forms the $H_3 P$.

The effect of fusion in the Electric Arc on Calcium Phosphide

"To test this, I obtained the carbide obtained by Frank and Hilpert's phosphorus process, which contained 1·38 per cent. of phosphorus. This carbide was not fused, and gave, by the action of water, a gas which was spontaneously inflammable. This carbide was then fused in the electric furnace, and I obtained a carbide, with 1·26 per cent. of phosphorus, which gave a gas not spontaneously inflammable. This refined calcium carbide was heated to 220°, and vapour of phosphorus allowed to pass over it, and when cold it was digested with carbon bisulphide to remove any free phosphorus. It contained 1·42 per cent. of phosphorus, and showed spontaneous ignition on decomposition by water. This product, again fused in the electric furnace, gave a carbide with 1·32 per cent. of phosphorus, showing no spontaneous ignition when decomposed by water.

Caro's conclusions

"From these researches I concluded that in the electric furnace only one calcium phosphide is formed, giving no spontaneously inflammable phosphuretted hydrogen. This does not prove that a mixture of acetylene and air is not ignited by this phosphuretted hydrogen if the quantity is sufficient for the heat of its oxidation to raise the temperature to the ignition point. Lewes found that this does not occur in mixtures

containing less than 15 per cent. of phosphuretted hydrogen.

Effect of temperature of generation on the form in which Phosphorus is present

"Calcium phosphide being present in the carbide, the phosphuretted hydrogen is always found in the acetylene liberated from it independent of the method of generation. But there exist differences in the products obtained qualitatively and quantitatively according to the temperature of the generation of the gas. With generation at low temperatures, only phosphuretted hydrogen was obtained; with high temperatures organic phosphorus compounds could also be detected.

Separation of the organic Phosphorus compounds

"The separation of these two kinds of compounds could only be done very incompletely; the gas was first washed in a wash bottle with petroleum ether, and then passed through sodium hypochlorite solution. After evaporating the petroleum ether a small quantity of a body containing phosphorus remained, whilst the distillate contained some more phosphorus compounds. The residues from the distillation and the petroleum ether were shaken up for a long time with sodium hypochlorite. The quantities obtained, although working with 5 kgr. of carbide, were so small that these tests could only be used for comparison. Tested in this manner the distribution of the phosphorus contained in the carbide, in which the total quantity had been estimated by fusing a quantity of carbide with sodium carbonate and saltpetre and precipitation of the phosphoric acid, could be traced:—

Distribution of the Phosphorus present in the products

"Generator, carbide into water.

In the gas 82·0 per cent. as phosphuretted hydrogen.
,, ,, ·2 ,, ,, organic compounds.
In the residue 17·8 per cent. calculated by difference.

Generator, dripping apparatus.

In the gas 52·2 per cent. as phosphuretted hydrogen.
,, ,, 14·3 ,, ,, organic volatile compounds.

In the gas 2·1 per cent. as organic non-volatile compounds.

"In the residue 31·4 per cent. calculated by difference.

Nature of the organic Phosphorus compounds

"The nature of these organic phosphorus compounds could not be determined, but the remarkable result was found that in the presence of ammonia in the gas the organic substances, both volatile and non-volatile, contained nitrogen. The results show also the peculiar fact that in dipping apparatus the gas generated contains less phosphorus than is present in the acetylene generated by dropping carbide into water.

The formation of Hypophosphites by the action of hot Alkaline liquids on Phosphuretted Hydrogen

"This seems very remarkable, but the higher temperature in the dipping apparatus may be the explanation. It is known that phosphuretted hydrogen at ordinary temperatures is only slightly attacked by alkalies, but that at higher temperatures this substance acts on alkalies with formation of hypophosphites. This reaction, discovered by Winkler, gives an explanation of the fact found by Dulong, that the phosphides of calcium, barium, and strontium give by rapid decomposition hypophosphoric acid.

Hydrogen formed at the same time as Phosphuretted Hydrogen

"This reaction also partly takes place when phosphuretted hydrogen is made from potassium hydrate and phosphorus, and the gas thus prepared always contains hydrogen:—

$$PH_3 + KOH = PH_2OK + H_2$$ [1]

The presence of Hypophosphites in the Lime residue

"Whether the presence of hydrogen in acetylene is due to this reaction could not be determined. The presence of hypophosphites in the lime residue was tested by dissolving a part of the residue in hydrochloric acid and boiling. Phosphoric acid was found, and phosphuretted hydrogen also. This corresponds with the reaction of hypophosphorous acid:—

$$2H_3PO_2 = PH_3 + H_3PO_4.$$

[1] Most probably $PH_3 + KOH + H_2O = KH_2PO_3 + 2H_2$.

"The discovery of the fact that phosphuretted hydrogen at high temperatures does not exist in the gas—but remains as hypophosphorous acid, or its oxidation products—in the residue caused me to test for the presence of phosphuretted hydrogen as an impurity occurring with "dipping" forms of apparatus. I had formerly (*Zeit. f. Beleuchtungswesen*, 1898, 134) noted that in this form of apparatus the peculiarity exists that in the first stages of the evolution of the gas a quantity of phosphuretted hydrogen was found much higher than the standard quantity previously stated by Liebetanz in his book. I have found that this phenomenon only occurs when the generator is filled with pure water, but when working as usual, or when after filling the generator with limewater, the contrary takes place, the quantity of phosphuretted hydrogen diminishing to the standard figure.

Phosphuretted Hydrogen in the gas generated in "Dipping" apparatus

Influence of the water on the amount of Phosphuretted Hydrogen formed

"This phenomenon, being based on the decomposition of phosphuretted hydrogen by alkaline liquids at a high temperature, has the practical result that the greater amount of phosphuretted hydrogen in the dipping apparatus can be avoided when starting if the apparatus is not filled with pure water but with limewater, *i.e.* water with some lime sludge in it.

Conclusions

"I conclude from these researches that with generators with a low temperature the amount of phosphuretted hydrogen is greater than with those of higher temperature, but in the latter other phosphorus compounds are less than in the former."

Renault finds that a mixture of Calcium Phosphides may be formed in the electric furnace

A. Renault,[1] in studying the reduction of calcium phosphate by carbon in the electric arc, found that under certain conditions a mixture of calcium phosphides was produced, which when treated with water gave rise to both gaseous and liquid phosphuretted hydrogen. In all probability the calcium phosphides formed were the tricalcium diphosphide, Ca_3P_2, and

[1] *Compt. Rend.*, 1899, 128, 883.

dicalcium diphosphide, Ca_2P_2, which would interact with water as follows:—

Action of the Phosphides on water

$$Ca_3P_2 + 6H_2O = 2PH_3 + 3Ca(HO)_2$$

and

$$Ca_2P_2 + 4H_2O = P_2H_4 + 2Ca(HO)_2.$$

It is perfectly clear, however, from these researches, that with a well-made and properly-fused carbide there is no fear of spontaneous ignition from phosphuretted hydrogen in the gas, and that the great drawback to its presence is the formation of its combustion products.

The formation of Hypophosphites explains the presence of Phosphorus compounds in condenser liquor

The interesting observation, that when phosphuretted hydrogen is heated with calcium hydrate hypophosphites are formed, is fully borne out by the fact, repeatedly noticed by the author, that in the drip boxes of a generator liable to heating, the liquid collected always contains phosphorus in the form of hypophosphites combined with the lime which has been brought forward as dust by the rush of gas during generation, and which has collected with the water condensed from the gas.

A sample of liquid taken lately from the drip box of a generator was found to contain:—

Analysis of liquid from condenser

	Grams per litre.
Lime	16·28
Sulphur	6·92
Phosphorus	4·01
Iron and alumina	0·19
Ammonia	7·14

With "Dip" generators there is a larger formation of Phosphuretted Hydrogen at first than later

Caro,[1] in an earlier paper than that just quoted, noticed with a "dip" generator, in which high temperatures were developed, that, during the first moments of generation, the gas evolved was unusually rich in phosphuretted hydrogen, and that using a carbide yielding an average of 0·038 per cent. of phosphuretted hydrogen 0·5 per cent. was observed

[1] *Zeit. f. Beleuchtungswesen*, 1898, 134.

in one experiment and 0·8 per cent. in a second during the first few moments of generation; and he concludes from this that at the first impact the water principally decomposes the calcium phosphide. Liebetanz repeated these experiments and confirmed Caro's observation.

It seems hardly possible from a theoretical point of view that it can be so, as the calcium phosphide is shown by experiment to be very evenly distributed throughout the mass of carbide, and if an artificial mixture of granulated carbide and phosphide is made, the acetylene certainly is generated more quickly than the phosphuretted hydrogen, and Caro explains it in the paper just quoted as being due to there being no lime at first to form hypophosphites.

The action of the electric arc on metallic Sulphides

In 1896, Murlot[1] showed that at the temperature of the electric furnace the sulphides of zinc cadmium and aluminium remained undecomposed, and it is manifest that they might therefore be present in calcium carbide; but the only one of these three of which traces are ever likely to be found in carbide is the aluminium sulphide, and as this is known to be decomposed by water, with evolution of sulphuretted hydrogen, the presence of this gas in crude acetylene has, ever since the date of Murlot's research, been ascribed to the presence of alumina and sulphur as impurities in the crude material from which the carbide was made.

The source of the Sulphuretted Hydrogen found in crude Acetylene

Calcium Sulphide and Calcium Sulpho-Carbide

Moissan[2] has also shown that calcium sulphide was present in the residues left by the decomposition of calcium carbide, by sugar solution, and the decomposition of this substance at the temperatures existing in some forms of generator would also yield sulphuretted hydrogen.

If there be much calcium sulphate present in the

[1] *Compt. Rendu.*, 123, 57 [2] *Compt. Rendu.*, 127, 457.

lime used for making the carbide, a calcium sulpho-carbide is also produced.

In making acetylene from carbide the amount of sulphuretted hydrogen which finds its way into the gas varies very considerably with the form of generator and the temperature of generation, and Caro[1] has attempted to estimate the distribution of the sulphur existing in the carbide on decomposition.

Caro's experiments on the distribution of the Sulphur in the products of a "Carbide into water" generator

25 kgr. of calcium carbide were well mixed, and 5 kgr. were first decomposed in an apparatus in which the carbide dropped into water. The acetylene was passed through a cotton wool filter, then through two washers filled with lead acetate solution, and afterwards through two washers filled with a mixture of ether and petroleum spirit, being then led into a 150 litre gasholder. From this holder it was burnt and tested photometrically during the evolution. The test for sulphur was made as follows:—The lime sludge in the generator was nearly neutralised by hydrochloric acid, and the liquor removed.

Analytical details of the experiments

An aliquot part was acted upon by a hydrochloric acid solution of a copper salt, and the resulting copper sulphide was weighed. The residue left was dried, fused with sodium carbonate and saltpetre, and the sulphur estimated as barium sulphate. The sulphur precipitated in the washers as lead sulphide was oxidised by nitric acid and weighed as lead sulphate. The liquid from the washers filled with ether and petroleum spirit mixture was distilled, the residue dissolved in a little ether and petroleum spirit, and oxidised with nitric acid at 120–150°, and the sulphur estimated as sulphate.

With the apparatus in which the carbide drops into water the following quantities of sulphur were found:—

[1] *Zeitsch. Calc. Acet.*, 2, 337.

Experimental result

a. Residue soluble in hydrochloric acid .	14·74	gr.
b. Residue insoluble in hydrochloric acid	1·66	,,
c. Substance soluble in ether-petroleum spirit	0·06	,,
d. In acetylene—lead nitrate . . .	3·00	,,
Sulphur . .	19·46	,,

The gas finally obtained was passed through a tube heated to redness in which were two boats containing lead chromate: these contained no sulphur after the reaction.

Distribution of the Sulphur compounds

In this experiment, therefore, we obtained from 5 kgr. of carbide 19·46 gr. sulphur, of which 3·06 gr. had passed into the gas (15·72 per cent.). Of this 3·00 gr. (15·41 per cent.) are present as sulphuretted hydrogen, and 0·06 gr. (0·31 per cent.) as organic compounds soluble in ether and petroleum spirit. In the residue there remained 14·74 gr. or 15·74 per cent. of sulphides, and 1·66 gr. (8·53 per cent.) in a more stable form.

Experiments with a "Dripping" apparatus

Totally different results were obtained in a dripping apparatus. For this purpose a Butzke apparatus (old form), was used, and the water only allowed to drop slowly, the apparatus being fitted with a special tap. Quantities of 250 gr. of calcium carbide were decomposed at a time, and then the acetylene was displaced by nitrogen through the above-mentioned tap. The gas mixture only passed through the washers but not to the gas-holder.

The same methods as before described were used, and the following results obtained:—

a. Residue soluble in hydrochloric acid .	1·08	gr.
b. Residue insoluble in hydrochloric acid	0·16	,,
c. Dissolved in ether petroleum spirit .	3·36	,,
d. In acetylene—lead nitrate . . .	13·94	,,
Sulphur . .	18·54	,,

i e. 0·92 gr. less than in the first experiment. It may

Distribution of the Sulphur compounds

be accepted that this was contained in the gas flowing into the holder, because I found sulphur in the lead chromate.

There were in the gas—

71·12 per cent. as sulphuretted hydrogen.
17·26 „ „ as sulphur compounds soluble in ether-spirit.
4·72 „ „ as sulphur compounds insoluble in ether-spirit.

In the residue—

5·55 per cent. as sulphides.
0·82 „ „ in a more stable form.

A repetition of this experiment was made with the modification that the water tap was opened more, and greater quantities of water run in at once. The result was—

Result of increasing the rate of flow of the water

a. Residue soluble in hydrochloric acid .	0·06	gr.
b. Residue insoluble in hydrochloric acid	0·12	„
c. Dissolved in ether spirit . . .	4·98	„
d. In the acetylene—lead nitrate . .	11·82	„
e. Final gas by difference	1·58	„
Sulphur . .	18·56	„

Hence there were in the gas—

60·79 per cent. as sulphuretted hydrogen.
45·59 „ „ as sulphur compounds soluble in ether-spirit.
8·11 „ „ as sulphur compounds insoluble in ether-spirit.

In the residue—

4·93 per cent. as sulphides.
0·61 „ „ in a more stable form.

Experiments to determine the influence of Aluminium in the Carbide

The carbide used contained, as nearly all the carbides do, a certain amount of aluminium. Having a sample of carbide which did not contain even a trace of aluminium, said to be from Bitterfeld works, I repeated the experiments with this sample, but only with 1·70 kgr. instead of 5 kgr. as before.

In the apparatus where the carbide drops into water the following results were obtained :—

a. Residue soluble in hydrochloric acid	.	4·16 gr.
b. Residue insoluble in hydrochloric acid		0·02 ,,
c. Dissolved in ether-spirit	. . . .	0·00 ,,
d. In the gas—lead nitrate	. . .	0·12 ,,
e. Final gas	. . . .	0·00 ,,
Sulphur	.	4·30 ,,

Hence there were in the gas—

Distribution of the Sulphur with "Carbide into water" generators

2·78 per cent. as sulphuretted hydrogen.
0·00 ,, ,, as sulphur compounds soluble in ether-spirit.
0·00 ,, ,, as sulphur compounds insoluble in ether-spirit.

In the residue—

96·74 per cent. as sulphides.
0·46 ,, ,, in a more stable form.

Using the dripping apparatus—

a. Residue soluble in hydrochloric acid	.	0·21
b. Residue insoluble in hydrochloric acid	.	0·01
c. Dissolved in ether-spirit	. . . .	0·62
d. In the gas—lead nitrate	. . . .	2·32
e. Final gas by difference	. . .	1·14

Hence there were in the gas—

Distribution of the Sulphur with "Drip" generators

53·95 per cent. as sulphuretted hydrogen.
14·41 ,, ,, as sulphur compounds soluble in ether-spirit.
26·51 ,, ,, as sulphur compounds insoluble in ether-spirit.

In the residue—

4·88 per cent. as sulphides.
0·23 ,, ,, in a more stable form.

Caro's conclusions

The results of these researches are —

That the acetylene evolved from apparatus in which the carbide drops into water is much cleaner than that generated in dripping apparatus is confirmed. The sulphur is nearly all converted into sulphuretted hydrogen, which is for the greater part retained in the generator. With carbide free from aluminium no sulphuretted hydrogen is set free, the calcium sulphide is dissociated in presence of much water, the sulphuretted hydrogen does not escape, and the gas evolved only contains traces of sulphuretted hydrogen.

The gas from the dripping apparatus contains more sulphur because there is only a small quantity of sulphuretted hydrogen retained, and moreover a quantity of the more stable sulphur compounds is decomposed. The dripping apparatus also produces a gas in which a great part of the sulphur is not in a form which is precipitated by lead salts, but as other compounds. The nature of these substances could not be determined. One is soluble in ether-petroleum spirit, the other does not seem to be taken up by this mixture, but escapes with the gas. Neither are precipitated by lead salts. The portion soluble in ether-petroleum spirit consists, as the odour proves, of sulphocyanides. The substances not removed by ether-petroleum spirit are oxidised by concentrated chromic acid solution, and are removed by acid cuprous chloride solution. They do not seem to be acted upon by chloride of lime. I believe they consist chiefly of mercaptans.

Presence of Sulpho-cyanides and Mercaptans

Probable presence of Sulpho-carbides in residue

The research on the residue insoluble in dilute hydrochloric acid was of special interest. It was tested separately, and its sulphur was found to be 1·48 per cent. This residue was decomposed by boiling hydrochloric acid, and sulphuretted hydrogen was evolved. Only a very minute quantity, containing 0·32 per cent., was tested, by fusing with sodium carbonate and saltpetre. When boiled with concentrated hydrochloric acid small quantities of hydrocarbons are produced, so that it is probable that this sulphur in a more stable form is a sulphocarbide compound."

Caro concludes from these results that the sulphur is present as calcium sulphide and aluminium sulphide, partly also in a more stable form as calcium sulphocarbide. The calcium sulphide and aluminium sulphide give, in both classes of generator, sulphuretted hydrogen, whilst the sulphocarbide is only decomposed in dripping apparatus owing to the high temperature. The sulphuretted hydrogen condenses in dripping ap-

paratus, and produces compounds partly of the type of sulphocyanides and partly other organic compounds, probably mercaptans. In the water to carbide generators these reactions do not occur, or only in a less degree.

In a later paper Caro[1] sums up these results as follows:—

The occurrence of Sulphur in Carbide

"Sulphur principally occurs in three different compounds as calcium sulphide, calcium sulphocarbide and aluminium sulphide. The two first compounds are due to the presence of calcium sulphate in the lime and to sulphur in the coke used. The quantity of both compounds can be reduced to a minimum, because the high temperature of the electric furnace causes these compounds to be split up by the carbon, with formation of calcium carbide and sulphur, which may be oxidised to sulphur dioxide. This has already been recognized by Dollner and Jacobsohn in their process for manufacturing sulphur or sulphur dioxide from sulphate or sulphides.

Aluminium Sulphide

"The aluminium sulphide occurs if sulphur and alumina are present. This compound is aluminium pentasulphide, Al_2S_5, as stated by Murlot, and is not decomposed by the high temperature of the electric furnace. This quantity also may be diminished by using an excess of carbon, as the aluminium sulphide is decomposed into aluminium carbide and sulphur.

Variation in products according to the temperature

"These compounds give, with water, impurities containing sulphur, but different ones under different conditions. Aluminium sulphide is decomposed by water, if cold or warm, with evolution of sulphuretted hydrogen. Calcium sulphide is dissociated by cold water; it therefore gives off sulphuretted hydrogen only at high temperatures. Calcium sulphocarbide is decomposed neither by cold nor hot water, but

[1] *Zeitsch. Calc. Acet.*, 3, 97.

gives at a higher temperature with acetylene volatile sulphur products.

Sulphur reacts with Acetylene at high temperatures

"The sulphuretted hydrogen set free is retained at lower temperatures by the lime sludge. At high temperatures it reacts with acetylene and forms organic sulphur compounds. I succeeded in identifying sulphocyanides and mercaptans. They are mixed with other compounds containing sulphur, and may be divided into two classes—

a. Those soluble in petroleum spirit and ether.
b. Those insoluble in petroleum spirit and ether.

In presence of ammonia basic compounds are found containing sulphur and nitrogen.

Superiority of "Carbide into water" generators

"With carbide into water apparatus all sulphuretted hydrogen is retained by the lime, only organic sulphur compounds being found in the gas evolved. In dipping apparatus there are greater quantities of sulphur, from the decomposition of the calcium carbosulphide. In the residue there is much less sulphur, whilst the greater part is evolved as sulphuretted hydrogen, and more organic compounds are formed."

Sulphuretted Hydrogen due to primary action

Caro[1] has continued this investigation in order to ascertain if the organic sulphur compounds formed during the generation of acetylene are due to primary or secondary actions, and finds that the primary action gives rise to sulphuretted hydrogen only, but that any undue heating at once causes secondary actions between the sulphuretted hydrogen and acetylene (or other hydrocarbons produced by the action of the heat on acetylene), which form organic sulphur compounds.

He also found that the oily matters obtained from the condensation products from large generators contained considerable quantities of sulphur, and that on heating, especially in the presence of steam, they decomposed and evolved sulphuretted hydrogen.

[1] *Zeit. f. Calc. Carb. und Acet.*, iii. 217.

Caro concludes from this that the sulphuretted hydrogen found in the crude acetylene may arise from two sources: (1) the direct liberation of the gas from such impurities in the carbide as aluminium sulphide, and (2) by the decomposition of organic sulphur compounds by heat and steam.

Organic Sulphur compounds due to secondary reactions

The variation in the amount of sulphur present as sulphuretted hydrogen in gas owing to the form of apparatus used was tested by the author in the experiments with twenty-four generators of different types before alluded to (page 421).

Practical experiments with generators

An average of 600 cubic feet of gas was generated from each apparatus in a test lasting for one month, and the sulphur present in the water of the meter attached to each apparatus was determined, with the following result for each class:—

Class of generator.	Sulphur. Grains per gallon.	Sulphur. Grams per litre.
Water dripping on carbide . .	24·2	0·34
Carbide dipping in water and then withdrawn	25·2	0·35
Water rising to carbide . . .	27·9	0·39
Carbide into water	18·0	0·25

At first sight this seems to show that, with the exception of the carbide into water generators being superior to the others, there was but little to choose between them; but on comparing the individual results with the pressures at which the generators worked it was at once seen that this exercised an enormous influence, some forms of generator, working with displacement holders and at pressures of over 24 inches of water, having over 70 grains of sulphur per gallon (0·99 grs. per litre) in the meter water; and if these abnormal cases be eliminated, and only the results given by generators working at less than 12 inches pressure compared, the figures at once showed the superiority of the last two classes of generator.

Influence of the class of generator and pressure on impurities

Polis' results

Polis found that on taking a sample of carbide and decomposing it by the dripping process there was present 0·138 per cent. of phosphuretted hydrogen and 0·064 per cent. of sulphuretted hydrogen; whilst if this carbide is allowed to fall into water the acetylene so generated contains 0·126 per cent. of phosphuretted hydrogen, and the sulphuretted hydrogen is practically eliminated.

When the carbide is dropped into a solution of sugar the same result is obtained, and practically no sulphuretted hydrogen can be detected in the gas so generated.

The presence of metallic Silicides in Carbide

The presence of metallic silicides in the calcium carbide has been amply demonstrated by the researches of Moissan, Le Chatelier, Gerard, Lewes, and others (see page 330), and there is not the slightest doubt but that siliciuretted hydrogen is often to be found in small quantities in the crude acetylene. The method of formation of this gaseous compound, however, is not so clear, as the metallic silicides found in the carbide are none of them decomposed by water, even at the high temperatures occasionally existing in generators. The most probable explanation of its formation is that given by Vigouroux,[1] who points out that, amongst the metals contained in the crude materials from which the carbide is made, iron alone forms crystalline silicides, whilst calcium, magnesium, and aluminium dissolve silicium, and that on acting on an alloy of calcium and silicium with water, the nascent hydrogen formed by the decomposition of the water by the calcium unites with the silicium forming siliciuretted hydrogen. It must be remembered that when carbide has been kept too long in the arc some is dissociated with liberation of metallic calcium, and the formation of an alloy with silicium under these conditions is extremely probable.

Vigouroux explains the formation of the Siliciuretted Hydrogen sometimes present in crude Acetylene

An alloy of Calcium and Silicium present in Calcium Carbide

[1] *Compt. Rendu.*, 123, 113.

The presence of traces of arseniuretted hydrogen in crude acetylene has been detected by some observers, and could only be formed owing to traces of arsenic compounds in the original materials.

Ammonia in crude Acetylene

Undoubtedly the most important impurity, next to the phosphuretted and sulphuretted hydrogen, is ammonia. The causes leading to the formation of this compound have been studied by Bamberger[1] who finds that the impurities in acetylene fall into two classes according to their origin, viz. (1) those which result from impurities in the raw materials used in the manufacture of carbide, such as phosphuretted hydrogen and sulphuretted hydrogen, and (2) those produced in the process of fusion in the electrical furnace, such as ammonia and cyanogen compounds. As ammonia is oxidised to oxides of nitrogen when the gas is burnt, much importance attaches to means for preventing its occurrence. When calcium carbide is decomposed with water ammonia is formed from both nitrides and cyanogen compounds. The nitrides result from the presence of aluminium or magnesium in the line. In the electric furnace magnesia is reduced in the first instance to magnesium, which is then converted into the nitride through the agency of the nitrogen of the air, which always circulates to a certain extent in the furnace, or of the small quantities of nitrogen which exist in the coal, coke, or charcoal employed. Aluminium is contained as alumina in most samples of lime, and is present in the silicates in coke ash. Alumina is reduced by carbon to the metal or to aluminium carbide. Aluminium carbide always contains nitride, as may be proved by decomposing a sample with water, and, when the evolution of almost odourless gas has ceased, adding excess of caustic soda and warming, whereupon ammonia will be given off in sufficient quantity to be readily detected by the smell.

Bamberger's conclusions as to the cause of the Ammonia

Nitrides present in Carbide

[1] *Zeits. f. angew. Chem.*, 1898, 31, 720

The power possessed by Carbides of absorbing Nitrogen

Carbides, especially barium carbide, possess the power of absorbing nitrogen at high temperatures and producing cyanogen compounds. Cyanogen may be detected by its smell on opening a closed vessel in which hot carbide has been allowed to cool. Ammonia, is formed by the action of superheated steam on calcium cyanide, and local superheating often occurs in the usual methods of producing acetylene from carbide. Carbide made from wood charcoal and lime, containing 0·5 per cent. of magnesia and 0·2 per cent. of alumina, was decomposed by dropping water on to samples weighing from 50 to 70 grams. The gas formed was led through standardised sulphuric acid, and was found to contain from 0·05 to 0·15 per cent. by volume of ammonia. Even the outer crust of the blocks of carbide, and small fragments which had cooled while exposed to the air, did not yield a higher proportion of ammonia.

Experimental results

The influence of the form of generator on the amount of Ammonia

The method by which the acetylene is generated affects the proportion of ammonia in the gas. The drip system of generation allows almost the whole of the ammonia to pass into the gas, and the high temperature favours decomposition of aluminium nitride and calcium cyanide. The dip and flooding systems occupy a mean position between the drip system and that in which carbide is dropped into water. The latter system is the best, because the trifling rise in temperature does not suffice to cause decomposition of calcium cyanide and aluminium nitride, and the surplus water in the generator absorbs the greater part of the ammonia. With an apparatus belonging to this system, which has been in continuous use since December, 1897, ammonia has scarcely been detected in the gas, but is easily recognized in the water in the generator.

Caro, with regard to Bamberger's conclusions, says: "Nitrogen is in the carbide as calcium and magnesium

nitride, formed principally from the nitrogen of the coke. These nitrides are decomposed by water, with evolution of ammonia and the formation of hydroxides of the metal. The formation of ammonia is, according to Bamberger, due to the presence of calcium cyanide, this idea being based on Frank and Caro's discovery that nitrogen forms with carbides nitrides.

Caro criticises Bamberger's conclusions

"The numerous tests I have made prove that calcium cyanide does not occur in fused carbide, and can only be found in the crust of the carbide ingot, which does not generally occur in commercial carbide. This also corresponds with Frank and Caro's statement that the temperature of the decomposition of calcium cyanide is lower than the temperature of the formation of carbide; therefore no cyanide can be formed except by the action of atmospheric nitrogen on cooling ingots. The product of the decomposition of the nitride—ammonia—is formed as well at a low as at a high temperature. Its quantity in the gas varies very much. In carbide into water apparatus more than 90 per cent. is dissolved; in dipping apparatus a good quantity condenses with sulphuretted hydrogen, as well as with phosphuretted hydrogen and with acetylene. The tar from these forms of apparatus is treated with hydrochloric acid, when these compounds dissolve, and may be extracted with ether."

Cyanides not present in fused Carbide but only in crust of ingot

Variation in the amount of Ammonia present in the gas partly due to other impurities

In the author's experiments on the influence of the class of generator on the impurities formed, it was found that the average of the ammonia present in the meter water of the various forms of apparatus was—

	Grains per gallon.	Grams per litre.
Dripping apparatus	67·1	0·95
Dipping „	19·0	0·27
Water rising „	60·4	0·86
Carbide into water	11·2	0·16

but as soon as the generators with displacement holders working at pressures of over 24 inches of water were

Pressure in the generator

an important factor

left out of the averages, and only the generators working below a pressure of 12 inches of water were considered, the water rising to carbide generators showed nearly the same results as the carbide into water class.

This clearly shows the importance of keeping the generator pressures as low as possible if the purity of the gas is to be considered.

Ludstrom first drew attention to the presence of carbon monoxide in crude acetylene, but no explanation has been offered as to the causes which give rise to it.

Carbon Monoxide in crude Acetylene

Occasionally a blow-hole in a piece of dense carbide is found to contain this gas, which has evidently been produced by the reduction of the lime by carbon in the electric arc; but the quantity is so minute that the presence of carbon monoxide in the gas cannot manifestly be traced to this cause. The author has found that, when any quantity greater than the merest trace of carbon monoxide is present, hydrogen is also to be found in the gas, and that it is never present unless over-heating has taken place in the generator.

The moment sufficient over-heating has taken place to break up some of the acetylene the steam present at once attacks the liberated carbon with formation of carbon monoxide and hydrogen, an action which will take place at the temperature necessary to cause the polymerisation of acetylene into benzene.

Causes which give rise to the formation of Carbon Monoxide

It is not necessary, however, to have a temperature sufficiently high to decompose the acetylene into its constituents, as on passing acetylene and steam through a tube heated to 500° C. oxides of carbon and hydrogen make their appearance.

A good deal of the carbon monoxide undoubtedly becomes oxidised at the temperature of its formation by the excess of steam present into carbon dioxide, but this is rarely found in the gas, being absorbed by the moist lime residue.

Hydrogen, which is often found in acetylene in considerable quantities, owes its production to several distinct causes.

Causes which lead to the formation of free Hydrogen in crude Acetylene

1. The decomposition of water by calcium present in over-heated carbide.
2. The decomposition of steam by heated hydrocarbons or carbon.
3. The decomposition of acetylene by heat.

When the acetylene is made in a properly constructed generator, and at a temperature below the boiling-point of water, it is only the first cause that can give rise to it, and only very small traces can be detected, but when overheating in the generator takes place, the acetylene may become so diluted with hydrogen and carbon monoxide as to seriously affect its illuminating power, and, according to some observers, even to render it nearly non-luminous.

Traces of air in Acetylene

Traces of nitrogen and oxygen are often shown in analyses of acetylene, and are generally derived from small quantities of air mixed with the gas during the collection of the sample for analysis.

Moissan has shown, however (page 334), that nitrogen is to be found in commercial carbide.

The vapours of Hydro-carbons other than Acetylene

The vapours of benzine and other volatile hydrocarbons, although not as a rule classed as impurities, certainly ought to be considered, as they give rise to a considerable amount of trouble in the combustion of the acetylene.

The action of over-heating on Acetylene

The moment that acetylene is subjected to the action of high temperatures, changes of great complexity at once commence. These at first are purely synthetical. At 600° C., however, acetylene begins to condense to benzene, and as the temperature rises the condensation of four molecules of acetylene yields styrolene. A further increase in the temperature may cause the styrolene and benzene to interact, yielding anthracene and hydrogen, and it is prob-

ably at this point that the brown tar vapours appear, while naphthalene also becomes noticeable. These changes, however, still have to be accurately studied. At this temperature, moreover, a fresh set of interactions start: the nascent hydrogen combines with acetylene to form ethylene, and this body, under the action of heat, breaks down to methane and acetylene once more.

Loss of volume from polymerisation

The earlier actions of necessity lead to a great loss in the volume of the acetylene. Dr. Haber found that 15 litres of acetylene, when heated for a considerable period to 638° C. left only 10 litres of gas; probably, however, no such condensation as this takes place in an acetylene generator. When the outer layer of carbide decomposes, the gas is evolved so rapidly that there is no time for the heat to act upon it, but as the decomposition spreads into the centre of the mass, the acetylene generated has to pass through the outer layers, which, as has been shown, may be at a temperature above the point of its decomposition, and it is under these conditions that a considerable volume of gas is lost, and the tar often found in the residue, or distilled out into generator and tubes, is formed.

The cause of the polymerisation

The formation of tar

In generators in which excessive heating takes place, this tar is likely to cause considerable trouble, as it is of a very viscous character, and if it condenses in the tubes causes the lime dust and carbon particles to collect and bring about stoppage.

Benzene vapour and its influence in causing smoking

As benzene forms a large proportion of the polymerisation products, it is carried forward as vapour, and remains suspended even in its passage through the gasholder and delivery pipes. Benzene requires three times the volume of air for combustion that acetylene does, and the result is that the most perfect acetylene burner shows a tendency to smoke directly any quantity of benzene is formed.

The action of Benzene on the burner-tip

Still more serious, however, is the action on the burner tip. One of the greatest troubles in the utilisation of pure acetylene is the question of finding a burner in which to consume it, and it was soon realized that the best of the burners first introduced could only be used for a few hundred hours before a growth of carbon appeared on the nipple, which distorted the flame and brought about smoking of the most pronounced character. It was thought that this trouble had been overcome by the introduction of the Naphey burner and the various imitations thereof that were at once put upon the market; but extended experience shows that even these burners are not infallible, and many who have watched the continuous use of acetylene, especially in those parts of the Continent where the gas has been adopted in a pure state as a town supply, declare that the burner question is as far from solution as ever. If a burner which has started smoking be examined, an arborescent growth of filiform carbon is noticed at the aperture or slit, and the general idea is that this has been formed by the overheating of the acetylene by the nipple causing its decomposition with formation of the carbon deposit. On breaking the steatite top off the burner it is found that the burner is carbonised for a considerable distance into the body of the steatite, and it is manifest that this has been caused by the deposition of a liquid hydrocarbon, which has soaked into the material and been carbonised there.

The Naphey burner

The formation of Carbon at the burner

Carbonisation of the burner caused by liquid Hydrocarbons

The condition of vapours in the Acetylene

If smoke or tar vapour be examined under a high microscopic power, it is seen that they consist of minute vesicles or bubbles in a most marvellously active condition of movement, and fulfilling in a most perfect manner the conception one forms of molecular motion. Ever bombarding each other, but never colliding, these small vesicles filled with gaseous matter continue their career until some mechanical

action bursts them and deposits the minute trace of liquid which formed the skin of the microscopic balloon.

Washers for removing vapours

It is for this reason that the most successful forms of washer for extracting tar during the manufacture of gas consists of fine jets or orifices through which the gas passes at considerable velocity, and comes in contact with a baffle which breaks up the vesicles; and any one with experience in water-gas making knows the trouble that arises from filiform growths of carbon, when, owing to an insufficient temperature in the cracking and superheating chambers, the carburetted gas contains vapours instead of permanent gaseous products.

The actions leading to the deposition of Carbon at the burner-tip

When acetylene has been made in a generator at an undue temperature it carries with it benzene vapour, which, as it commences to condense, assumes this vesicular form, and on coming to the extremely minute holes which form the aperture of the burner, the mechanical scrubbing which it encounters causes the breaking up of the vesicles and the deposition of the benzene and other hydrocarbons held in suspension by benzene, which soak into the steatite and carbonise. The presence of finely divided carbon has a great effect in determining the decomposition of acetylene itself, so that a rapid growth of carbon takes place at the burner, and no ordinary cleaning of the deposited carbon from the exterior will ever make the nipple fit for constant use again, because the carbon in the pores has a strong catalytic action on the acetylene, and causes carbon to again deposit.

Smoking decreased by cool generation

It will be found with experience that the prevention of smoking in a burner will be overcome quite as much by attention to the temperature in the generator as in the burner itself, and where a generator is in use which gives overheating, a well-arranged scrubbing apparatus that would get rid of the benzene

from the gas would be found a distinct advantage in stopping burner troubles.

Impurities that need not be removed

Of the impurities present in the acetylene, some, such as hydrogen, carbon monoxide, and traces of air, are perfectly harmless, and in the small quantities formed, when the gas has been generated in any but the worst forms of generators, do not in any noticeable manner affect its illuminating power.

Injurious impurities

On the other hand, phosphuretted hydrogen, sulphuretted hydrogen, ammonia, and hydrocarbon vapours should be as far as possible removed, as they either form deleterious products of combustion, or act on the fittings and burner-tips.

Of these impurities, the only one that offers any real difficulty in removal is the phosphuretted hydrogen, and several methods have been proposed and utilised for its elimination.

Necessary conditions to be fulfilled by a purifying agent

It is obvious that for small house installations of acetylene lighting, which constitute so large a proportion of its field of utility, it is necessary to have the purifier as simple as possible, and to utilise only one form of purifying material, as otherwise the process would become too complicated for the ordinary householder to care to undertake it. Moreover, it is necessary that the purifying material employed, whilst removing or at any rate reducing the impurities to a harmless limit, should be cheap, and not itself liable to act upon the acetylene or generate other products that might cause trouble in the purifier, or further contaminate the gas.

Pictet's purification

Beyond washing the acetylene by allowing it to bubble through water, no attempt at consistent purification was made until 1896, when Pictet proposed to purify the gas before using it for liquefaction by pressure. In order to do this, he proposed to pass it through a concentrated solution of calcium chloride and then through sulphuric acid, both being kept

at a low temperature (– 20 to – 40° C.); after this, the gas passed through a washer containing a solution of lead salts to eliminate sulphuretted hydrogen, and was finally dried by passing over solid calcium chloride.

Drawbacks to the process

It is manifest that such a method would be costly and utterly unfitted for working on a small scale, whilst it is very problematical whether the purification effected would be sufficient to rid the gas of phosphuretted hydrogen.

Purification by Potash and Bromine

Willgerodt[1] suggested purifying acetylene by first removing sulphuretted hydrogen by passing the gas through a solution of potassium hydrate and then absorbing the phosphuretted hydrogen with bromine water. This method could not be used on any but a laboratory scale, and the same may be said of the process suggested by Berge and Reyschler,[2] who proposed to remove the sulphuretted hydrogen and phosphuretted hydrogen by passing the gas through an acid solution of mercuric chloride.

Acid Mercuric Chloride as a purifying agent

As the necessity for purification became more and more apparent, many experiments were made to provide some material, the price of which should make its use commercially possible, and which should eliminate the impurities at one operation, and at the present time there are three substances recognised as fulfilling these conditions:—

Substances commercially available for the purification of crude Acetylene

1. Bleaching powder.
2. Acid solutions of copper or iron salts.
3. Acidulated solution of chromic acid.

The use of bleaching powder for the purification of acetylene was first proposed and patented by Smith of Aberdeen,[3] and later was advocated by Lunge and Cedecreutz,[4] who point out that bleaching powder can be employed for this purpose on account of its cheap-

[1] *Berl. Ber.*, 28, 2,102.
[2] *Bull. Soc. Chem.*, 3, 17, 218.
[3] Eng. Pat. 24,414 (1896).
[4] *Zeit. f. ang. Chem.* (1897), 654.

ness, and say, "It can be used as a solution or thin liquor through which the acetylene is permitted to pass. It is more convenient, however, to use bleaching powder in the solid form in the presence of sufficient moisture to secure a good working. According to experiments, the best way is to form the bleaching powder into lumps with a small quantity of water, so that the gas can pass through readily: the pulverised powder offers too much resistance, and also causes dust to rise. It would be better to arrange behind the vessel holding the bleaching powder another containing lime, which would catch anything brought through from the bleaching powder.

Bleaching powder as a purifier

On the other hand, the bleaching powder must not contain so much moisture as to become pasty, and thus prevent the gas from penetrating. When the acetylene is too moist it can be cooled, the condensed moisture removed, and thus almost dry gas obtained. Of course, a chemical drier, such as concentrated sulphuric acid, of gravity 1·6 to 1·7, is better. This drier, or one less concentrated, can also be used to remove the ammonia, or other acids can be used in its place for the same purpose.

Condition in which the bleaching powder should be used

By using more vessels, they can be replaced when exhausted, others put in their place, and the calcium phosphate and sulphate removed."

Bleaching powder, or, as it is often commercially called, chloride of lime, is made by passing chlorine over carefully slaked lime containing about 25 per cent. of its weight of water, every precaution being taken during the action of the chlorine on the lime not to allow any rise of temperature. This material, when properly made, contains about 36 to 37 per cent. of available chlorine, *i.e.* chlorine which can again be set free; and this material is largely utilised for bleaching purposes owing to the fact that as it undergoes slow decomposition, the chlorine evolved from it

Preparation and action of bleaching powder

unites with the hydrogen of the moisture present and liberates oxygen, which combines with any oxidisable substances with which it is in contact.

Action of bleaching powder on the impurities in the Acetylene

The action of bleaching powder in purifying the acetylene is purely an oxidation process, as the phosphuretted and sulphuretted hydrogens, being more readily attacked than the acetylene, are oxidised to phosphoric acid and sulphuric acid, whilst the acetylene is unaffected.

In practice, the bleaching powder is generally mixed with some inert substance, to expose a larger surface to the gas, sawdust being frequently used for this purpose on a large scale, whilst some makers of purifying material use small proportions of bodies that have little or no specific action to mix with the bleaching powder and to give it a distinctive colour. The material used by Thorn and Hoddle in their purifier consists of bleaching powder with a little oxide of iron; whilst Wolff's purifying material is bleaching powder with a little lead chromate.

Ahrens' experiments with bleaching powder as a purifier

Ahrens[1] has studied the action of bleaching powder, and mixtures containing it, on crude acetylene, and states its advantages and disadvantages as follows:—

"To enable the bleaching powder to act better, it was slightly moistened and mixed with sawdust so as to obtain a larger surface. It was found, however, that lumps of varying size had been formed through which the gas did not penetrate, as it naturally passed round them through the loose layers, thus the purifying material was apparently exhausted, when in reality large quantities of the bleaching powder were unused; moreover, the purified gas had to pass through a drying apparatus containing in this instance calcium carbide, a substance often used for this purpose. The result was a dry gas, but one rendered impure by the acetylene set free in the drying process. Calcium

[1] *Zeit. Calc. Acet.*, 3, 81.

carbide, therefore, was not a good drying material, and could not remove any traces of chlorine from the gas. It was therefore thought best to use the bleaching powder in a finely divided condition, and to employ lime as the drying agent. This method was found to be good. Wolff, having recognised this, prepares the bleaching powder as a uniform yellow powder, the yellow being due to the addition of lead chromate, which is added to facilitate the powdering, and merely acts as a diluting material. On treatment with water, a green solution is obtained, which shows that a chromic salt is present, but the quantity is so small that its action in purifying may be neglected. The oxidation value of Wolff's bleaching powder is high. My experiments show that with acetylene passing at the rate of 25 litres per hour, one kilogramme purifies 18,000 litres of the gas completely from all sulphur and phosphorus compounds. Sixteen litres of gas were allowed to pass through a 10-bulb tube filled with pure sodium hypobromide, and then several times through a 5 per cent. potassium permanganate solution. By these means nearly all the sulphur and phosphorus compounds would have been oxidised, but in no case could any sulphuric or phosphoric acid be found.

Condition of the bleaching powder used

Purifying power of Wolff's mixture

"Wolff has published a statement in *Kraft und Licht*, 1892, No. 32, that the gas purified by his bleaching powder has an odour of chlorine. It is difficult to see why the gas should possess a bad odour. Chlorine compounds of acetylene have a sweet smell, similar to that of purified acetylene, and the conclusion must be drawn that other hydrocarbons, whose presence has been found in several generators, may yield, with chlorine from the bleaching powder, compounds having such an odour. In my generator, however, in which carbide falls into water, I have never observed it. The gas, after passing through the bleaching powder,

Smell of Acetylene purified by Wolff's mixture

Presence of Carbon Monoxide

always had a sweet ethereal smell. The gas, however, is not yet pure, as, if it is passed through a blood solution, this latter shows the carbon monoxide spectrum. If potassium permanganate be used for oxidation of the gas, as mentioned above, it may be employed for the quantitative determination of the chlorine. That pure acetylene was acted on by bleaching powder was shown by several experiments. Pure acetylene, *i.e.* containing no sulphur, phosphorus, or chlorine, was allowed to pass through a Wolff's tower, and then through permanganate solution, and a considerable quantity of chlorine was found. In other experiments, however, the bleaching powder tower was followed by one containing lime, and then the gas passed through the permanganate solution. In this case the quantity of chlorine was much less, though always considerable, the tests being made with the greatest care.

Necessity of passing Acetylene purified by bleaching powder through Lime

"By passing acetylene through Wolff's purifying substance it is, therefore, totally freed from phosphuretted hydrogen and all organic sulphur and phosphorus compounds, but carbon monoxide and organic chloride compounds are formed which will accompany the gas. That such organic chlorine compounds are formed in the bleaching powder was proved by treating the exhausted material with ether and subsequent evaporation, but the quantity found was not great."

Ahrens investigates the cause of free Chlorine in purified Acetylene

Later, Ahrens[1] investigated the cause of the free chlorine found in the acetylene purified by this process, and also the sudden rise in the temperature of the mass which is occasionally noticed when damp bleaching powder is mixed with sawdust.

"I have already shown that acetylene purified by bleaching powder retains the smell of chlorine, and that certain chlorine compounds are formed, but this does not affect the flame and the burners, though my

[1] *Zeit. Calc. Acet.*, 3, 173.

own experience is that the edge of the flame is somewhat changed. On the other hand, it is known that in many cases, by using bleaching powder as a purifying material, a very strong odour of chlorine was noticed. The town lighting of Vesprezen had to be stopped for some time because the odour of chlorine was so strong in the houses that the people could not stay in them. Another trouble was also experienced several times: the bleaching powder heated suddenly, and lost its purifying power at once. I have made researches on this point with the following results:—

Troubles with purification by bleaching powder

"At first I believed that a reaction between acetylene and chlorine took place, which might happen with a strong bleaching powder, though often having used the material of the best quality I had never observed any rise in temperature. I therefore tried to start the reaction by slowly heating the bleaching powder as high as 100°. It seemed that some acetylene was absorbed, the flame becoming smaller and smaller, but without being extinguished, no sudden reaction, however, taking place.

Action of bleaching powder on Acetylene

"I then tried bleaching powder mixture as it is employed in practice. I used a strong fresh sample mixed with sawdust and moistened with water. The ratio of these three was changed in different ways, and it was noticed that when using a certain amount of water, a rise in temperature took place reaching as high as 130° C. This heating does not appear directly the mixture is prepared, but only after a certain time, depending upon the ratio of the mixture. It is accompanied by the evolution of water vapour and chlorine. Both heating and evolution of water vapour and chlorine have the same cause, and do not at all depend on acetylene."

Rise of temperature observed with mixtures of sawdust and bleaching powder

This explanation will also show why the bleaching powder method of purification does not always yield good results. I have always stated that the bleaching

powder gives very high purification results. If the bleaching powder be weak owing to storage these phenomena do not occur.

The following table gives the results with mixtures of bleaching powder—34 per cent.—and sawdust with water.

Mixing 50 gr. of bleaching powder with 12·5 cc. of water, the temperature rises 11 to 12°, and goes down after a short time. 5 gr. sawdust and 4 cc. of water were then added, and after seven minutes, no rise of temperature being observed, 5 gr. sawdust and a little water were again added, then after ten minutes the temperature rose to 125°, and the mixture began to froth.

In order to show that heating was caused by the reaction of sawdust on bleaching powder, a strong cold solution of bleaching powder was mixed with sawdust, and after a short time the temperature rose to 95°.

The heating due to the action of Chlorine on the Lignine in the sawdust

Other experiments with pure cellulose and a bleaching powder solution gave almost no rise of temperature. It is therefore almost certain that the lignine substances of the sawdust react with bleaching powder with evolution of heat.

It therefore follows for practical purposes that the bleaching powder must be mixed with very much sawdust or very little water. The best way is to avoid the sawdust and to mix with kieselguhr, coke powder, brick powder, lead chromate—Wolff's mixture —or other materials."

Alleged formation of Chloride of Nitrogen

Some observers have stated that the highly explosive chloride of nitrogen is liable to be formed when bleaching powder is used as a purifying agent, owing to the ammonia present in the crude acetylene reacting with chlorine from the bleaching powder. It seems highly improbable that this should occur, and the author has never been able to detect any trace of

Experimental results

Bleaching Powder.	Sawdust.	Water.	Maximum from 0°.	Temperature reached in minutes.	Remarks.
grg. 30	gr. 20	cc. 5	45	10	
30	20	10	69	50	After 56 minutes, 5 cc. of water are added owing to decrease of temperature; temp. decreases to 61·5 and rises in 17 minutes to 118°.
30	20	15	120	4	After 3 minutes water vapour begins to be evolved.
20	30	12	117	7	
20	20	5	40	11	
20	20	8	66	15	
20	20	10	125	17	
20	20	15	123	5	After 3 minutes, strong evolution of steam, the mixture frothing.
20	20	20	115	3	After 1 minute strong evolution of steam.
20	20	30	116	4	
20	20	50	106	2	After 1 minute the mass boils.
20	10	8	46	12	Amount at which no reaction takes place in a not quite homogeneous mixture.
20	10	8	126	7	
20	10	9	130	7	
20	10	10	125	5	
20	7·5	5	39		The rise from 21° to 37° takes place when mixing bleaching powder with water.
20	7·5	8	52	20	
20	7·5	10	128	6	Boiling and frothing of the mass.
20	7·5	15	127	6	Frothing of mass, filling beaker.
20	5	5	37		
20	5	8	46	6	
20	5	10	49	10	
20	5	12	125	4	Violent frothing.
20	5	15	116	6	After 4 minutes the mass begins to froth so that it overflows the beaker.
20	5	30	110	8	After 6 minutes, the same.
10	20	10	76	5	Some evolution of steam and a little chlorine.
7·5	20	10	71	7	The beaker is bedewed.
7·5	20	15	76	5	
7·5	20	20	79	2	
·5	20	10	64	7	The beaker is bedewed.

this action taking place, but it can be rendered absolutely impossible by the use of an acid washer to abstract all ammonia from the gas before the purifier is reached.

Stagnant gas from purifier gives slight smell on burning

One of the great drawbacks to this method of purification is that in warm weather, on first lighting the gas in the evening, there is a slight smell of hydrochloric acid, as the gas that has stood for probably twenty-four hours in the purifier is consumed.

This slight trouble can readily be got over by passing the gas through a layer of lime after it leaves the purifier.

There is no doubt as to the purifying power of the material, and the following table of results, obtained with Wolff's mixture of bleaching powder and lead chromate, shows that when using ordinary carbide, 1 kilo of the mixture will purify 21 cubic metres—742 cubic feet—of acetylene :—

Purifier Filled with 8·5 kg. of Material.

July 7th, 1899.

Installation for 100 lights.

Practical results as to the purifying power of Wolff's mixture

Date.	Gas passing through Purifier.		Before Purification. Per cent.		After Purification. Per cent.	
	cb. m.	c. ft.	H_2S.	PH_3.	H_2S.	PH_3.
July 11 . .	14	494	0·015	0·059	0·00	0·00
„ 14 . .	26	918	0·005	0·044	0·00	0·00
„ 19 . .	43	1,518	0·01	0·05	0·00	0·00
„ 22 . .	54·5	1,924	0·011	0·071	0·00	0·004
„ 26 . .	67·5	2,384	0·005	0·031	0·00	0·00
Aug. 1 . .	79·5	2,706	0·0032	0·147	0·00	0·001
„ 14 . .	110	3,883	0·0044	0·158	0·00	0·0013
„ 19 . .	129	4,554	0·0052	0·048	0·00	0·00
„ 22 . .	138	4,871	0·067	0·051	0·0008	0·001
„ 29 . .	162	5,719	0·0056	0·052	0·001	0·0013
Sept. 1 . .	175	6,177	0·0092	0·059	0·0013	0·0015
„ 4 . .	182	6,415	0·0064	0·057	0·0018	0·002

8·5 kg. material purified 182 cb. m.—6,415 c. ft.
1 „ „ „ 21 „ 742 „

A new purifying material which owes its action to the presence of bleaching powder has lately been introduced by the Gold und Silber Scheide Anstalt of Frankfort, under the name of "Puratylene," and consists of a granulated mixture of lime and bleaching powder, this form of the material being very convenient, and offering but little resistance in the purifiers.

"Puratylene"

During the last few years a large number of cases have occurred of spontaneous firing and explosion when air has been admitted to bleaching powder purifiers which have been in use for some time. On several occasions, in large installations, on opening the box purifier in order to renew the material, a "flare" has occurred, whilst in other cases in which small purifiers containing bleaching powder have been used, and have been disconnected and left for some time, as acetylene has diffused out and air has diffused in, an explosion, often of a serious character, has taken place.

Spontaneous ignition and explosion with bleaching powder purifiers

It was at first supposed that these explosions were due to the formation of chloride of nitrogen; but this theory is untenable, as, in the conditions under which they have occurred, it has been made amply manifest that air is necessary for the action. It is well known that free chlorine will bring about the explosion of a mixture of acetylene and air, and it is manifest that in a purifier containing partly decomposed bleaching powder and acetylene, introduction of air with its contained trace of carbon dioxide might lead to the liberation of chlorine, and so bring about an explosion, whilst it is also possible that the liberation of hypochlorous acid by moisture and carbon dioxide might lead to the same result. At any rate, these explosions make it amply clear that bleaching powder should only be used as a purifying agent with the greatest precaution.

Conditions under which explosion has taken place

Purification by acid solutions of Copper and Iron Salts

The second method by which purification can be brought about is by passing the crude gas through acid solutions of copper or iron salts, and Goettig[1] used for this purpose an acidulated solution of copper sulphate mixed with some other substances not mentioned, whilst Frank[2] uses a hydrochloric acid solution of cuprous chloride, and this method is now very widely adopted.

The action of Acidulated Cuprous Chloride in purification

Frank[3] describes its action as follows: "This method of purification removes the ammonia, sulphuretted hydrogen, and phosphuretted hydrogen in one operation. The purified acetylene has not the characteristic odour of the crude acetylene, nor does it form explosive compounds in contact with copper, because the absence of the impurities prevents their formation. This method is based on the fact that these impurities are especially removed by solutions of the salts of those metals which form several oxides. To purify the acetylene it is bubbled through several washbottles containing a hydrochloric acid solution of cuprous chloride of definite strength. The ammonia is neutralised by the acid. The sulphuretted hydrogen and other sulphur compounds, such as polymercaptides, are transformed into cuprous sulphide, and the phosphuretted hydrogen is partly absorbed and partly precipitated as copper phosphide. Our experiments showed that one volume of this solution purified 12,000 to 14,000 volumes of acetylene. The gas escaping from the wash-bottles only needs washing with water to be nearly quite pure. The odour is then aromatic, and the gas contains traces of aldehydes. Whether these were derived from an oxidation of the acetylene could not be proved.

"The hydrochloric acid cuprous chloride solution is

[1] *Jour. f. Gasbel*, 59, 206. [2] Ger. Pat. 94490.
[3] *Jour. f. Gasbel*, 41, 615.

somewhat discoloured, and may be regenerated in the easiest way by boiling whilst air is passed through it, when it is again ready for use. The same effect is also produced with mercury and iron salts."

Regeneration of the purifying solution

In order to render this method of purification more convenient, Frank impregnates kieselguhr with his solution, the solid being easier to handle and giving less resistance in the purifier. It is also claimed for it that it can be regenerated after it is exhausted by seiving and exposure to air. This, however, is not so, though the breaking up of the material exposes fresh surfaces, and gives a slight renewal of the purifying power, but in practice this should not be reckoned upon.

Kieselguhr impregnated with the solution acts as a purifier

The objections which have been urged against Frank's system are that owing to the acid nature of the mass, ordinary metal containers cannot be employed, and also that if the acid became neutralised by ammonia or lime dust, the explosive copper acetylene might be formed. Frank replied to these objections,[1] and also gave further figures as to the efficiency of the process as follows: "Kieselguhr impregnated with the hydrochloric acid solution of cuprous chloride purifies as well as the solution itself, and has the advantage of only slightly decreasing the gas pressure. The material is specially fit for small apparatus, its volume in comparison to the surface being small, and it can also be used for town lighting installations, though on a large scale I should always prefer to bubble the gas through a solution, as less attention is required than with the kieselguhr. With the solution the regeneration is carried out as follows: The exhausted liquor is filtered, copper sulphide remains on the filter, the filtrate is boiled and air drawn through it. By boiling, the phosphuretted hydrogen escapes, and with a definite strength of solution does

Objections raised to Franks' purifier

Franks' answers to the objections

[1] *Zeit. Calc. Acet.*, 2, 298.

not form copper phosphide, but only an unstable compound of it with cuprous chloride. After having added a little copper, and brought it to the original volume with hydrochloric acid, the solution is again ready for use.

Advantages over bleaching powder

"The kieselguhr material is merely exposed to the air for regeneration. The purifiers now made are of such a size as to work from 3 to 6 months, and as the material does not change by keeping, it can easily be replaced by new owing to its cheapness. This is a great advantage when compared with bleaching powder, which loses chlorine even in closed vessels.

Vessels for containing the purifying material

"Wolff is of opinion that metal vessels could not be used for the acid solution or solid material, but this is a mistake. In chemical industries we have had, in a great many manufactures, enamelled iron vessels which have been in use for many years. Enamelled cylinders, perforated or not, could also be used, placed in metallic outer casings. These would have the advantage of being easily taken out, cleaned, and recharged. The formation of copper-acetylene is impossible on account of the amount of hydrochloric acid in comparison to the copper, so high an amount of ammonia being allowed for in the gas that the solution is exhausted before neutralisation occurs. The cuprous chloride in hydrochloric acid does not affect the acetylene itself.

"The time during which the purifying material could be used has been practically proved in Germany, America, and Switzerland on a commercial scale.

Cost of purification

"With 1 kg. of ferric chloride solution or solid material, 7 to 10 cb. m. of acetylene were purified; with 1 kgr. cuprous chloride solution, 18 to 25 cb. m. The copper method is better than the iron one. If the price is 6*d.* per kgr. for this material, the purification of the acetylene set free from 1 kgr. carbide is one-sixteenth to one-fifth of a penny. The possibility

of regeneration is not calculated in these figures, though this surely will be done when generating and purifying acetylene on a large scale.

Weight of material that should be used

"When illuminating houses and cottages with 20 to 30 burners, with a consumption per hour of 20 litres, in use for 6 hours a day, a purifier must be used containing 12 to 15 kgr. of the material. It has been stated that this quantity has been found sufficient for three to four months.

Conclusions

"The results of my practical researches are as follows: 1 kgr. of the material purifies 20 to 25 cb. m. of acetylene from all noxious substances. The acetylene is not acted upon by the material. The purified gas has a pleasant odour. The exhaustion of the purifying material will be detected by the appearance of the flame and the generation of noxious products of combustion, but the formation of copper-acetylene is not possible. The material acts regularly till exhausted, and does not change when kept."

Ullmann's purification by Acidulated Chromic Acid

The third method of purification consists in passing the crude acetylene through solutions of chromic acid containing sulphuric or acetic acid. This process, which is patented by Ullmann, is undoubtedly a good one, and is thus described by Ahrens.[1] Ullmann's purifying material consists of an acidulated solution of chromic acid. For big central stations the solution is found best, for single generators, kieselguhr impregnated with this solution is used.

The action of Acidulated Chromic Acid in purification

This purifying process destroys and eliminates in one operation phosphuretted and sulphuretted hydrogen and ammonia. The light yellow mass when used changes colour, and is converted into a dirty green. The exhausted mass exposed to air reverts to yellow, and therefore can be regenerated. The action of the chromic acid depends on oxidation processes, the yellow chromic acid being gradually converted into a chromic salt.

[1] *Zeit. Calc. Acet.*, 3, 81.

Results of Ullmann's purification

Ullmann's material gives good results. It eliminates all impurities except small traces of organic sulphur compounds, the presence of which could be several times found by the means stated above. Pure acetylene passed through a tower filled with the substance was not changed, no carbon dioxide, carbon monoxide, aldehydes or acids being formed. Absorption of acetylene does not occur. Berge's reagent showed an opalescence after 2,800 litres have passed over 1 kgr.

Wachs' experiments on Ullmann's process

Wachs[1] in Bunte's laboratory made some researches on Ullmann's process for purification. Two towers, 40 cm. high, were filled with pieces of pumice stone impregnated with a solution of crystallised chromic acid dissolved in twice its weight of 50 per cent. acetic acid. In the lower part of the towers the liquid stood 2 cm. from the inlet of gas tubing. After these two purifiers a third tower was connected containing lime and sawdust in order to remove acetic acid vapours. First it was noticed that acetylene at a rate of 29 litres per hour after passing the apparatus had entirely lost its penetrating odour. Using Berge and Reyschler's reagent (10 parts of mercuric chloride, 20 parts of 30 per cent. hydrochloric acid, and 80 parts of water), it was not rendered turbid after the gas had passed at the above rate for an hour. A flame, consuming 29 litres per hour in a room of 26 cb. m. capacity, did not produce the slightest haze, nor did the air affect the respiratory organs.

Results obtained

Purification effected

Quantitative tests were then made, Lunge's method being employed. The unpurified gas for 11·29 litres of acetylene gave 0·0205 gr. magnesium pyrophosphate. In a sample of the gas taken behind the purifiers 8·18 litres acetylene gave not a trace of ammonium magnesium phosphate nor a yellow precipitate with ammonium molybdate. Working as

[1] *Jour. f. Gasbel*, 42, 198; *Zeit. Calc. Acet.*, 2, 413.

indicated by Ullmann, the results obtained therefore are very good.

Another experiment was made. The rate of gas was increased beyond the limits allowed. A burner consuming 119 litres per hour was used, and after working $1\frac{1}{2}$ hours a slight haze was observed in the 26 cb. m. room. 14 litres of the gas passing both purifiers at a rate of 128·23 litres per hour were aspirated and tested, but only a small amount of phosphorus was found.

Influence of the rate of flow on the purification

In order to test the influence of chromic acid on the light emitted, the gas was tested photometrically, before and after purification. The test was in both cases the same. The gas passed the purifiers at a rate of 18·59 litres per hour. It was found 0·57 litres per Hefner unpurified, 0·58 litre per Hefner purified. To ascertain the quantity of chromic acid used, 812 litres were passed through chromic acid of known strength. The chromic acid was used in a Geissler absorption apparatus, the test lasted 552 hours, the gas bubbling very slowly. The gas was tested with sodium hypochlorite between 511 litres and 523 litres, and between 662 and 675 litres, but no phosphuretted hydrogen was found. 812 litres of acetylene used 4·04 gr. of chromic acid for purification. 1 cb. m., therefore, requires 5·5 gr. chromic acid. 100 kgr. of chromic acid costs 72*s.*, the purification of 1 cb. m. therefore costs 0·05*d.* With 1 kgr. of calcium carbide, yielding 300 litres of acetylene costing 5*d.*, 1 cb. m. therefore costs 1*s.* 4*d.*; the cost of the chromic acid would therefore be ·33 per cent. of the price of the gas.

Amount and cost of material used in purification

Ullmann and Miss Goldberg[1] made an interesting series of determinations of the purifying power of the acidulated chromic acid as compared with the power of the acidulated metallic salts. They say,

Experiments made to contrast the purifying power of

[1] *Jour. f. Gasbel*, 52, 374.

Franks' and Ullmann's systems

"In order to make the different tests comparable, it was necessary to have a homogeneous crude material. We did not try this by calcium carbide, but made a large quantity of acetylene and used it for the different tests. We had two gasholders, one of 150 litres and the other of 30 litres capacity, the latter graduated in 50 cc. Both holders were filled with brine saturated with acetylene.

Method of experiment

"In the big holder the gas was mixed by compression, and stood for 24 hours, being then allowed to pass into the smaller one, so that 15 to 20 litres were used for each test. This gas was allowed to pass through two ten-bulb tubes, each filled with 75 cc. of 3 per cent. solution; these solutions were acidified with dilute hydrochloric acid, evaporated to 100 cc., ammonia being then added, and the phosphoric acid precipitated with magnesium chloride, the sulphur in the filtrate being precipitated with barium chloride.

Analysis of crude Acetylene used

"I. Analysis of the original commercial acetylene: 100 litres of acetylene contain:

	I.		II.
Phosphorus ...	0·154	...	0·153 grams.
Sulphur ...	0·065	...	0·067 ,,

a. Action of Commercial Acetylene on Ferric Chloride.

Purifying action of Acidulated Ferric Chloride

"30 gr. of ferric chloride were dissolved in 100 cc. of a 10 per cent. hydrochloric acid, and the liquid obtained impregnated with 100 gr. of kieselguhr. The yellow mass was sifted and placed in a tower 20 cm. high and 4·7 cm. diameter. After the tower was filled with acetylene it was connected to the gasholder and the ten-bulb tubes, and the analysis made as above mentioned.

"100 litres of acetylene contained 0·151 gr. phosphorus and 0·065 gr. sulphur.

"These results show that ferric chloride has no purifying effect on commercial acetylene, and does

not diminish the quantity of sulphur or phosphorus. All the sulphur was present as so-called organic sulphur, no sulphuretted hydrogen being there. We intended using large quantities of the purifying material, and allowing the gas to pass extremely slowly in order to get the best conditions, but we know very well that such conditions would never be attained in practice. We, however, succeeded in completely proving the total inactivity of certain metallic salts.

b. Action of Chromic Acid on Commercial Acetylene.

Purifying action of Acidulated Chromic Acid

"The ferric chloride was taken out and the chromic acid material, as previously published (*Acet.*, W. & J., 1899, 28; *Jour. f. Gasbel*, 1899, 199) by one of us, was introduced, the experiment being repeated as before.

"100 litres of acetylene contained 0·000 gr. phosphorus and 0·002 gr. sulphur.

"These figures show that the chromic acid material completely eliminates the phosphuretted hydrogen, whilst only about 3 per cent. of the total sulphur remain in the gas. The analysis of the acetylene used gave the following figures:—

"100 litres of acetylene contained 0·137 gr. phosphorus and 0·016 gr. sulphur.

c. Action of Cuprous Chloride on Commercial Acetylene.

Purifying action of Acidulated Cuprous Chloride

"The cuprous chloride solution was prepared after the formula of Frank, which is the same as Caro (*Acet.*, W. & J., 1899, 9) published. 100 cc. of this solution were impregnated with 100 gr. of kieselguhr, the tower filled with it, and the experiment made as before.

"100 litres of acetylene contained 0·000 gr. phosphorus and 0·015 gr. sulphur.

"These figures prove that cuprous chloride destroys and eliminates all the phosphuretted hydrogen, whilst it is without any action on organic sulphur com-

pounds. These results prove the correctness of our opinion (*Acet.*, W. & J., 1899, 29), contrary to the statement of Caro (*Acet.*, W. & J., 1899, 19). They further prove that Berge's reagent is far more sensitive than silver nitrate.

d. Action of Chromic Sulphate on Commercial Acetylene.

Purifying action of Chromic Sulphate

"Quantitative tests have already shown that, as was to be expected, chromic sulphate had no purifying action on commercial acetylene. The quantitative analysis gave the following figures:—

"100 litres of acetylene contained 0·139 gr. phosphorus and 0·015 gr. sulphur.

"Comparing these figures with those of the acetylene used, it must be clear that chromic sulphate does not purify acetylene.

"These researches, based on quantitative tests, show that ferric and chromic salts are without any action, that cuprous chloride acts very well but not completely, and that chromic acid has a complete purifying action on acetylene."

It has been stated that acidulated chromic acid oxidises some of the acetylene, with formation of carbon monoxide; but with the strength of solution used by Ullmann this is not so.

Goettig's experiments on the action of Alkaline Chlorides in purification

Goettig [1] has found that the action of metallic salts in purifying acetylene can be considerably increased by the addition of alkaline chlorides in definite proportions. In describing his experiments he says:—

"The following methods have been in use hitherto for purifying acetylene gas:—1. Frank uses solutions of acid metallic salts. 2. Lunge and Cedercreutz, bleaching powder. 3. Willgerodt, bromine. 4. Berge and Reyschler employ mercuric chloride. 5. Pictet,

[1] *Berl. Ber.*, 32, ii. p. 1879.

saline solutions and acids at a temperature below—10° C. 6. Ullmann, chromic acid in acetic or sulphuric acid solution. In order to avoid the formation of explosive metallo-acetylene compounds, an excess of acid is necessary in nearly all these methods. The author has now found that the acid can be advantageously replaced by potassium or sodium chloride solutions, provided that they be mixed in certain definite proportions.

Acids replaceable by Alkaline Chlorides in purifying solutions

"*a.* 100 gr. of ferric nitrate, 10 gr. of copper sulphate, 10 gr. mercuric nitrate, 20 gr. of nitric acid (sp. gr. 1·2), and 1,000 gr. of water were mixed.

Solutions employed by Goettig

"*b.* The same solution was made, with the addition of 40 per cent. of a potassium chloride solution containing 20 per cent. of potassium chloride.

"50 cc. of each of these two solutions were placed in two wash bottles, crude acetylene being then passed through them into 20 cc. of a solution containing mercuric chloride and hydrochloric acid (sp. gr. 1·2), until a faint turbidity appeared. This occurred:—

"1. In four experiments, when solution *a* was used after passing through (1) 600, (2) 650, (3) 550, (4) 690 cc. of crude acetylene.

Results obtained

"2. Four experiments, solution *b*—(1) 2,400, (2) 2,500, (3) 2,700, (4) 2,800 cc. of the same gas.

"Similar experiments were carried out without the use of nitric acid.

"*c.* Solution *a* without nitric acid.

"*d.* Solution *a* with potassium chloride.

"Results:—

"*c.* (1) 1,050 cc., (2) 1,520 cc., (3) 1,250 cc., (4) 1,420 cc.

"*d.* (1) 5,725 cc., (2) 6,200 cc., (3) 5,200 cc., (4) 5,650 cc.

"It is evident from these figures, which are of course only of approximate accuracy, that the addition of

Goettig's conclusions

potassium chloride in place of acids to the above metallic salts solution increases very considerably the capacity for decomposing phosphuretted hydrogen, at the same time preventing the formation of explosive mercuro-acetylene compounds."

Practical results

A wordy warfare has raged upon the Continent amongst those interested in the three main types of purification, but when properly employed there is but little to choose between them, Frank's liquid purification showing perhaps the best results on a large scale, whilst for small installations either of the three give equally good results.

Stern suggests organic solvents

Stern has patented the use of organic solvents, such as paraffin oil, acetic acid, alcohol, or benzene for completing the purification of acetylene, and paraffin is also used in the purifier sold with the "Sunbeam" apparatus.

Exley's purifying slabs

Messrs. Exley & Co. make a purifier in which the gas has to pass through a plate or plates of porous earthenware. The action of such a filter is of course one of mechanical scrubbing, but they are effective in keeping back products of polymerisation limedust and excess of suspended moisture. By saturating these plates with solutions such as Frank's or Ullmann's, they can be made to give efficient purification for a short period, but the pores soon begin to choke and to offer resistance to the passage of the gas.

Limit of purification necessary in practice

In considering the subject of purification, it must be clearly borne in mind that chemical perfection is not the thing commercially needed. All that it is necessary to do is to reduce the impurities below the limits at which the products of combustion cease to become injurious to health or property, and if the phosphuretted hydrogen is reduced to 0·01 per cent., and the sulphur compounds to the same limit, the troubles incidental to impure acetylene practically disappear.

CHAPTER IX

THE GENERATION OF LIGHT AND POWER FROM ACETYLENE.

Illuminating value of Acetylene first observed

IN concluding his celebrated paper, in which he first recounted the discovery and properties of acetylene, Edmund Davy said: "From the brilliancy with which the new gas burns in contact with the atmosphere, it is admirably adapted for the purposes of artificial light if it can be procured at a cheap rate," a prophecy which, although sixty years have been taken in its fulfilment, has yet been amply verified.

Early photometric determinations of its illuminating value

It was in the autumn of 1894 that the author first received a supply of American carbide, and in reporting on this material and on the acetylene generated from it, in November of that year wrote: "The gas when mixed with an equal quantity of air can be burnt with a No. 4 Bray burner, and the illuminating power of the mixture would be equal to 65·7 candles per 5 cubic feet of gas consumed, which would give the acetylene an illuminating value of 131·4 candles per 5 cubic feet. The presence of an inert gas, such as the nitrogen in the air, is well known to exercise such a cooling power on the flame as to seriously reduce its illuminating value, and I find that if the acetylene be burnt by itself at a suitable burner, it develops no less than 230 candles per 5 cubic feet of gas consumed."

Acetylene yields 240 candles per

Further experiments made during December, 1894, with carefully purified gas yielded a slightly higher

5 cubic feet of gas consumed

result, and in the paper read before the Society of Arts in January, 1895, the author gave the illuminating power of the gas when burnt under the best conditions as being 240 candles.

The illuminating value of a gas

A considerable amount of vagueness exists as to what is meant by the illuminating value of a gas, and the only assumption which can be arrived at is that it is the highest illuminating result which can be produced from the gas without the aid of regeneration or artificial air supply other than that created by the flame itself.

Methods for attaining complete combustion

The proper combustion of any hydrocarbon gas, however rich, can be effected by supplying the flame with exactly the amount of air necessary to prevent smoking, and it is under these conditions that the highest illuminating result possible with the particular burner is obtained.

With flat flames the ratio between the air supplied and the gas consumed is governed by two factors—(*a*) the thickness of the flame; (*b*) the pressure under which the gas issues from the burner.

The effect of pressure on the combustion of a gas

When a gas issues from a burner under pressure, the uprush of the escaping gas mechanically draws in air, so that when consuming a poor coal gas in a flat flame the pressure has to be kept down, or too much air would be drawn in, which would consume the hydrocarbons too rapidly, and so seriously affect the amount of light emitted. As the gas increases in illuminating value, more and more air is required for proper combustion, and this can be obtained by increasing the pressure at the burner.

Experience has shown that with ordinary sized flat flame burners seven-tenths of an inch in pressure gives practically the best results with coal gas of the quality supplied in London, and up to a certain limit the same flat flame burner can be used for richer gases by increasing the pressure. When this limit is reached

a thinner sheet of flame has to be employed, *i.e.* a smaller burner used, low initial pressure resorted to, and then by increasing pressure this can be made to consume gases of increasing value, until the pressure reaches a point at which the flame becomes distorted, when a still smaller burner has to be taken. By such means as these even acetylene, with its enormously high illuminating value, can be satisfactorily consumed, whilst by thickening the flame and reducing the pressure to the point at which the uprush almost ceases to cause a mingling of air with the flame, and leaves the supplying of the oxygen to diffusion, even a poor gas can be made to develop its illuminating power.

Different pressures needed with different gases, when burnt from the same burner

On consuming acetylene from a 000 union jet burner at all ordinary pressures a smoky flame is obtained, but on increasing the pressure to four inches a magnificent flame results, free from smoke, and developing an illuminating value of 240 candles per 5 cubic feet of gas consumed. Slightly higher values have been obtained, but 240 may be taken as the average value under these conditions.

How the illuminating value of Acetylene is obtained

By far the most interesting, and at the same time important, chapter in the history of flame, however, is the consideration of the causes which lead to the luminosity of those flames upon which we depend for most of our domestic lighting; and these causes offer so beautiful a field for both physical and chemical research that they have attracted the attention of many observers, and form no inconsiderable addition to the chemical history of the century. In the year 1816, whilst engaged upon those celebrated researches which culminated in the discovery of the miner's safety lamp, Sir Humphry Davy noticed certain facts which led him to work out and propound his theory of the causes which led to luminosity in flame—a theory which is generally stated as being that the

The luminosity of flame

The researches of Sir Humphry Davy on flame

Sir Edward Frankland's "dense vapour" theory

presence of solid particles in the flame is essential to its luminosity. This theory remained unquestioned until 1868, when the late Sir E. Frankland, in his celebrated communication to the Royal Society, showed that although solid incandescent matter in a flame renders it luminous, luminosity is also in many cases produced when the flame contains very dense vapours at a sufficiently high temperature, and also that a non-luminous flame may be rendered luminous by increasing the pressure of the atmosphere around it.

Stein's defence of Davy's theory

This gave rise to a storm of criticism, and the next few years drew forth a rich crop of papers on the subject. Professor Frankland not only showed that flames might be luminous without containing solid particles, but advanced the theory that the luminosity in the flame of a burning gaseous hydrocarbon was due to dense hydrocarbon vapours, and pointed out that the soot deposited on any cool substance held in such a flame contained hydrogen. To this W. Stein replied, showing that the deposited soot contained less than 1 per cent. of hydrogen, which was therefore probably only occluded by the carbon; and also that, if it had been present as a vapour in the flame, it ought, on being heated to the same temperature as the flame, to become once more volatile, which it undoubtedly does not.

The researches of Soret and Burch

In the year 1874 Soret attempted to show that the cause of luminosity in flame really does depend upon the presence of solid particles by focussing the sun's rays upon a luminous flame and examining the reflected light by means of a Nicol prism; and rather later Burch pursued the same line of research, but employed the spectroscope for his examination of the reflected light. Their results point unmistakably to the presence of solid particles, and at the present time there can be but little doubt that, as far as the flames of candles, oil, and coal gas are concerned, Sir Humphry Davy's theory is the

correct one. Indeed, although it may seem that in some points Davy went a little too far in his theory, it is almost certain that in his own mind he applied his theory more especially to the flames of our ordinary illuminants, as in his original memoir he speaks of "common flames," and distinctly says that "when in flames pure gaseous matter is burnt, the light is extremely feeble," and again, "the intensity of the light of flames depends *principally* upon the production and ignition of solid matter."

Davy's theory now generally accepted

Whilst this war of solid particles *versus* dense vapours was raging, Hilgard, Landolt, Blochmann, and Heumann were trying to trace the chemical actions taking place in various flames, and the causes which led to the loss of luminosity when air was mixed with coal gas before combustion in the Bunsen burner. Heumann added the further proof to the "solid particle" theory of luminosity, in pointing out that all flames that owe their luminosity to incandescent solid matter give definite shadows, while those in which luminosity is due to dense vapours give none; and that candle, oil, and gas flames all cause well-defined shadows.

The researches of Hilgard, Landolt, Blochmann, and Heumann

Dewar and Liveing, in their paper "On the Origin of the Hydrocarbon Flame Spectrum,"[1] say, when speaking of the flame of cyanogen and acetylene, "Both of these compounds decompose with evolution of heat. In fact they are explosive compounds, and the latent energy in the respective bodies is so great that if kinetic in the separated constituents it would raise the temperature between 3,000° and 4,000°. The flames of cyanogen and acetylene are peculiar in respect that the temperature of individual decomposing molecules is not dependent entirely upon the temperature generated by the combustion, which is a function of the tension of dissociation of the oxidized products,

Dewar and Liveing on the flames of Acetylene and Cyanogen

[1] *Proc. Chem. Soc.* 1882, 34, 427.

carbonic acid and water. We have no means of defining with any accuracy the temperature which the particles of such a flame may reach. We know, however, that the mean temperature of the flames of carbonic oxide and hydrogen lies between 2,000° and 3,000°, and if to this be added that which can be reached independently by the mere decomposition of cyanogen or acetylene, then we may safely infer that the temperature of individual molecules of carbon, nitrogen, and hydrogen in the respective flames of cyanogen and acetylene may reach a temperature of from 6,000° to 7,000°.

They point out that the formation of Acetylene during combustion gives points of high local temperature

"A previous estimate of the temperature of the positive pole in the electric arc made by one of us gave something like the same value.

"The formation of acetylene in ordinary combustion seems to be the agent through which a very high local temperature is produced."

Guéquen attributes the luminosity of hydrocarbon flames to endothermic decompositions

M. Guéquen [1] pointed out that it was very probable that luminosity in hydrocarbon flames is due exclusively to the production of rays furnished by the molecules of gas highly heated by chemical changes, and says that it must be borne in mind that the heating from exterior sources would not suffice, whatever its power. He also drew attention to the fact that luminous combustion is caused by bodies which are endothermic, and from which heat is liberated during decomposition.

Lewes shows that in all luminous hydrocarbon flames Acetylene is formed before luminosity commences

In a paper read before the Chemical Society in 1892,[2] the author showed that in the inner non-luminous zone of a flame the hydrocarbons originally present in the gas, consisting of ethylene, butylene, benzene, methane, and ethane, became converted, by the baking action of the walls of flame between which they had to pass, into acetylene, and that at the

[1] *Compt. Rendu du Société Technique de l'Industrie du Gaz*, 1884, 142. [2] *Trans. Chem. Soc.*, 1892, 61, 322.

moment when luminosity commenced over 80 per cent. of the total unsaturated hydrocarbons present consisted of this compound.

The part played by Acetylene in the flame

The presence of acetylene at the point where luminosity commenced naturally suggested that it was in some way due to actions in which the acetylene played the principal part—either that it split up into carbon and hydrogen under the influence of heat, and so supplied the flame with the solid particles necessary, according to Sir Humphry Davy's theory of the cause of luminosity, or else that by its polymerisation it formed the dense vapours required by Dr. E. Frankland's more recent hypothesis.

Lewes' experiments on the action of heat on flowing hydrocarbons

In order to elucidate this point, the author carried out a long series of experiments upon the action of heat upon flowing ethylene and other hydrocarbons, which formed the subject of communications to the Royal Society in 1893 [1] and 1895,[2] in which he showed that, whilst flowing through a heated area—the temperature of which was between 600° and 1,000° C.—ethylene decomposed according to the equation,—

$$3C_2H_4 = 2C_2H_2 + 2CH_4,$$

and that the acetylene then polymerised into a large number of more complex hydrocarbons, amongst which benzene and naphthalene were conspicuous, whilst at temperatures above 1,200° C. no polymerisation took place, the acetylene formed from the ethylene decomposing at once into carbon and hydrogen, whilst the methane, which up to this temperature had been but little affected, decomposed into,—

$$2CH_4 = C_2H_2 + H_2,$$

The formation of Acetylene and its decomposition to carbon and hydrogen

and this fresh supply of acetylene at once broke up into carbon and hydrogen, so that at temperatures above 1,200° C. the complete action may be looked upon as being,—

$$C_2H_4 = C_2 + 2H_2.$$

[1] *Proc. Roy. Soc.*, 55, 90. [2] *Ibid.*, 57, 394.

These results have an important bearing upon the cause of the luminosity in the flame, as it is manifest that, if the temperature of the luminous zone is above 1,200° C., the light emitted must be due to incandescent particles of carbon, and not to incandescent hydrocarbon vapours.

A further series of experiments led to the enunciation of the acetylene theory of luminosity [1] already alluded to (p. 116), which is based upon the facts that,—

The facts upon which the Acetylene theory of luminosity is based

1. The largest proportion of the unsaturated hydrocarbons present in a gas flame are converted into acetylene before luminosity commences.
2. Acetylene develops luminosity when heated to a temperature at which it decomposes, the conditions under which this takes place rendering the presence of atmospheric oxygen impossible.
3. The temperature necessary to decompose acetylene with luminosity is insufficient to raise carbon to the point at which it emits light.
4. In luminous hydrocarbon flames of sufficiently high temperature the luminosity varies directly with the amount of acetylene present at the point where luminosity commences.

Pictet on the luminosity of Acetylene flames

In 1896 Pictet,[2] unaware apparently of the work which had been done on the subject, published the following explanation of the high luminosity of acetylene in his pamphlet, *L'Acétylène, son passé—son présent—son avenir*:—

The endothermic nature of the Acetylene molecule

" Acetylene is formed, as has been seen, by an endothermic reaction. The hydrogen and carbon united in a molecule of acetylene contain a vast amount of energy supplied to them at the moment of their com-

[1] *Proc. Roy. Soc.*, 57, 450. [2] Geneva, 1896.

bination. This amounts to more than 2,700 calories per kg. of acetylene. At the dissociation of the molecule of acetylene this energy is liberated, and distributes itself equally between the hydrogen and carbon.

"These two bodies are formed in their gaseous state in the molecule of acetylene; they are then in the most favourable condition for absorbing this—that is to say, for using it without changing the gaseous state of the carbon.

"In the voltaic arc the carbon absorbs a considerable quantity of heat in passing from a fused to a volatilised condition. These changes in the carbon take place when the temperature in the electric arc reaches 3,500°, as has been demonstrated by M. Moissan. This is the maximum temperature of the arc, corresponding to the volatilising point of the carbon under atmospheric pressure.

The temperature of the carbon separating from the Acetylene molecules

"In the combustion of acetylene, on the contrary, the molecule of carbon, separating from the gaseous hydrogen, receives all the energy enclosed therein, and the temperature rises to 4,500° or 4,800°—a height unique in the annals of chemistry, this being the explanation of the light-giving power of acetylene."

Smithells on the Acetylene theory of luminosity

Smithells[1] has strongly opposed the "Acetylene Theory of Luminosity" mainly on the grounds that there is no evidence of more than a trace of acetylene at any point within an ordinary luminous flame, the acetylene that is formed being so diluted with other gases that there is no reason for supposing that it is of primary importance in the emission of light; also that there is no evidence of any local condition of temperature within the flame such as would point to the decomposition of acetylene with the evolution of much heat, and that the phenomena of luminous hydrocarbon flames can be adequately explained without the acetylene theory.

[1] *Chem. Soc. Jour.*, 67, 1,050.

The light yielded by Acetylene

Be the cause of luminosity what it may, there is no doubt as to the wonderful illuminating power of the acetylene flame ; and, as before stated, it is possible to burn it in a flat flame burner in such a way as to develop light from it in the ratio of 240 candle power per 5 c. ft. of acetylene produced.

This figure is the one quoted by most manufacturers of acetylene apparatus, who argue from it that acetylene is fifteen times as valuable in illuminating power, volume for volume, as London coal gas.

The fallacy of the usual commercial comparisons

Such a comparison is, however, absolutely misleading, as in contrasting the value of acetylene with coal gas one must always bear in mind that the illuminating power of the London gas is determined by consuming it at the rate of 5 c. ft. per hour in the London argand, whilst in practice any power from 8 to 90 candles can be obtained from this volume, according to the form of burner in which it is consumed. Although small flat flame burners only emit from 1 to 2 candles per cubic foot of gas consumed, good incandescent mantles will yield about 18 candles per cubic foot, and certainly 17 on the average ; and as incandescent lighting is rapidly displacing other methods of burning gas—and as this tendency will be enormously increased when the lapsing of the Welsbach monopoly reduces the price of the mantles to the figure now charged in Germany —it is evident that no calculation is fair that does not include this as a factor.

Limit of size in burners using Acetylene

Moreover, a very short experience shows that burners consuming 1 c. ft. of acetylene per hour are the largest that can be practically used for domestic purposes, and that, taking such burners all round, 32 candles per cubic foot is a fair average of the light developed by them, although out of a big batch of burners you occasionally find a few which will go as high as 36 or even 40 candles per foot. The influence which the size of the burner and the rate of consumption have

upon the illuminating power of 16-candle London coal gas is well-known, and is shown in the following table :—

Flat flame burner.	Candles per cubic foot.
No. 7	2·44
„ 6	2·15
„ 5	1·87
„ 4	1·74
„ 3	1·63
„ 2	1·22
„ 1	0·85
„ 0	0·59

Influence of the size of the burner on the light obtained from coal gas

and as the consumption of acetylene is regulated by exactly the same factors as act in the case of coal gas, it is evident that the smaller the burner and consumption the lower will be the candle power per foot of acetylene; and in practice with a one-half cubic foot burner 24 candles per cubic foot is a good result.

Taking a series of burners of the Naphey type, obtained from Falk, Stadlemann & Co., the following results were obtained :—

Number of burner.	Pressure—inches.	Gas consumed—cubic feet.	Light—candles.	Candles per foot.
6	2·0	·155	0·7938	5·3
8	2·0	·27	3·2	11·6
15	2·0	·40	8·0	20·0
25	2·0	·65	17·0	26·6
30	2·0	·70	23·0	32·85
42	2·0	1·00	34·0	34·0

Influence of the size of the burner on the light obtained from Acetylene

From these considerations it is evident that the only fair way to contrast the light obtainable from coal gas and from acetylene, unless it is distinctly stated that mantle-lighting is excluded, is to take the incandescent burner on the one hand, and the 1 c. ft. flat flame on the other, when it is seen that, instead of being fifteen times the value of coal gas as an illuminant, acetylene has only about twice its power.

Early forms of burners used for Acetylene

When acetylene was first introduced, the smoky character of the flame led to its being burnt, in America, mixed with an equal volume of air, whilst later the author attempted to burn it alone at Bray nipples of the character used for rich oil gas, which gave very fine results when pressures of 3 to 4 inches were employed. In order to do away with the necessity for this somewhat high pressure, the author had cubic foot burners made, in which the union jet holes in the steatite tip were made very fine, and at a more obtuse angle than in the burner designed for oil gas,

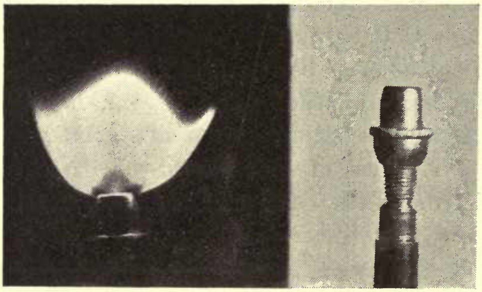


Fig. 177.

this causing a greater insuck of air into the flame and a corresponding improvement in the combustion.

Lewes burner

These were mounted in manganese steel, instead of in brass, the idea existing at that period that copper alloys should not be used in the construction of acetylene fittings.

These burners, Fig. 177, proved the most successful of any made up to that time, and were not only used in England, but were also supplied to Hempel in Berlin, who sold them under his own name.

Bray burners

Early in 1895 Bray made specially small burner tips for use with acetylene, Fig. 178, and both these nipples answered extremely well for a time, developing 30 to 36 candles per cubic foot of gas; but they both had

the same weakness, and after a few hundred hours began to smoke, and as a smoking acetylene flame covers everything in a room with a thick deposit of soot in a very short space of time, such burners were

The smoking of Acetylene burners

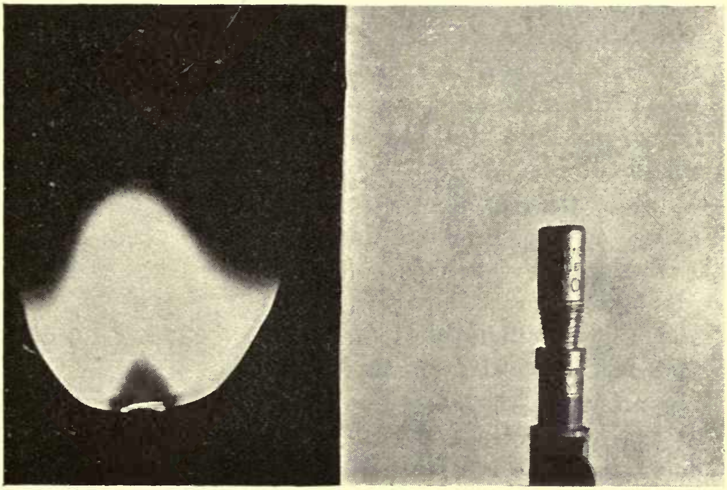


Fig. 178.

manifestly not fitted for the work they had to perform.

Carbon growths on the burner

The trouble generally commenced with a filiform growth of carbon appearing at the nipple (Fig. 179), which quickly distorted the flame, and caused a cloud of soot flakes to descend. If the burner was cleaned and relighted, the trouble commenced again in an hour or two, and the only thing to be done was to replace the nipple by a new one.

If the nipple had been burning some time, and was then removed and broken, it was found to be carbonised for some depth into the material, showing that a liquid hydrocarbon had soaked into the material, and had been there split up by the heat, with deposition of carbon.

The cause and the attempts at prevention

The generally accepted idea was that the heat of the nipple polymerised some acetylene to benzene, and this, forming a drop, did the mischief, consequently efforts to keep the burner cool were looked upon as a likely direction in which to search for success. Experiments have lately been made by Bullier in this direction, and he finds a very considerable gain in illuminating power is obtained when the head of the burner is kept cool by a small water jacket.

Fig. 179.

Early French burners

Whilst these troubles were going on in England, in France single jets made of glass were first employed, and then Bullier in 1895 introduced the idea of mixing air with the acetylene at the burner tip, and in so doing gave the inception of the host of burners of this type which at present exist and which have proved the most successful for the consumption of the gas.

Bullier's burners

The burners constructed by Bullier were made both for flat flames and argands.

In the flat flame nipples (Fig. 180), the gas passed from the delivery pipe through two narrow apertures, *a a*, to the nozzle, the uprush of the acetylene drawing in air through the two lateral tubes, *b b*, these tubes slanting upwards, and joining the acetylene orifices at a point immediately below the burner top. In this form of burner the air mixed with the acetylene just before its combustion, but in his argand burner (Fig. 181) the acetylene aperture had a cap, *c c*, fitted above

it, at the apex of which was an opening wider than the acetylene aperture, and above this cap the acetylene burnt.

The importance of the Bullier patents as anticipating the modern form of burners

The cap being fixed a short distance above the acetylene jet, and being open at the bottom, formed a channel on each side of the jet, up which air was dragged by the uprush of the acetylene, and although some air would mix with the acetylene, the larger portion undoubtedly formed a layer or envelope which prevented actual contact between the acetylene and

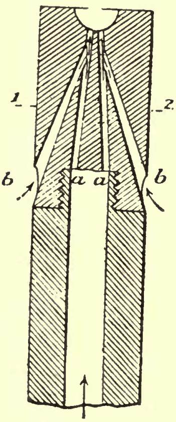


FIG. 180.

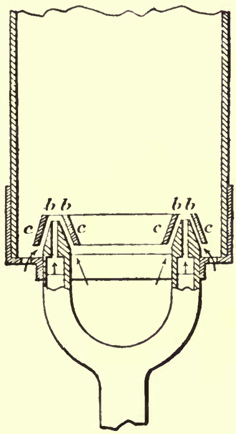


FIG. 181.

the heated apex of the burner, and, although Bullier's burners were never a commercial success, they form a serious anticipation of the more modern developments. Bullier also introduced a small burner of the Bunsen type, in which the acetylene entering a wider tube through an injector at the bottom drew in the air needed for its incomplete combustion through lateral air-holes.

Holliday burner

Later in 1895 Holliday constructed a burner which was practically a small Bunsen bottom with a slit nipple at which the mixture of acetylene and air,

formed and mixed in the tube below, burned with a flat flame, which from the low pressure at which the mixture was burnt was very susceptible to draughts, and gave an illuminating value of 20 to 25 candles per cubic foot of acetylene consumed. In November, 1895, Gearing took out a patent in which the acetylene was mixed with air immediately before combustion, whilst Cruveillier also made a burner of

Cruveillier burner

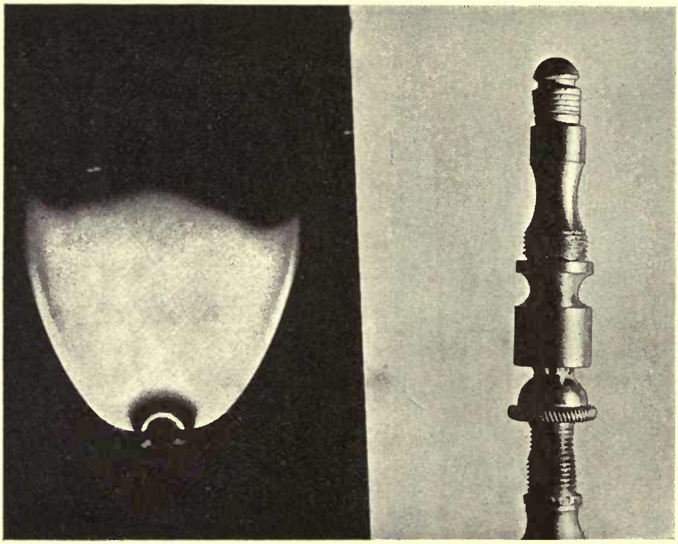


FIG. 182.

this type in which the lower portion consisted of an injector jet for the acetylene, surmounted by a series of air-mixing cones of the same construction as those used by Bandsept in his Bunsen for incandescent mantles, the mixed air and acetylene being consumed from a big flat flame burner.

Burners of this type, but drawing in air from under a cap instead of at a side hole, have been lately re-introduced (Fig. 182), but the results obtained with them are no better than with double jet burners.

The burner troubles of 1895

It was at this period that the troubles connected with the consumption of acetylene looked as if they were likely to raise insurmountable difficulties in introducing this beautiful illuminant; the union jet and slit flat flame nipples smoked after they had been in use for some time, the single glass jets gave but poor illuminating value, whilst such burners as the Bullier and Holliday had hardly passed the experimental stage.

Double jet flat flame burners

At the end of 1895 and early in 1896 Ragot, Risener, Luchaire, and others introduced the idea of making two tubes, leading from the base of the burner curve towards each other in such a way that the two jets of flame should impinge upon each other at some little distance from the nozzles and mutually splay each other out into a flat flame, in this way forming a "union jet" in which the base of the flat flame was at a distance from the issuing point of the acetylene into the air.

This arrangement showed a marked improvement upon the earlier forms of burner, as more air was sucked into the flame, and the nozzles from which the acetylene issued were not subjected to the same degree of heat as in the ordinary flat flame burners, with the result that nearly 30 candles per foot of acetylene was obtained as the illuminating value, whilst the troubles incidental to smoking became much less.

The Billwiller burner

Later in 1896 Billwiller introduced a burner (Figs. 183, 184), in which Bullier's principle of enveloping the flame with air was wedded to the double jet just referred to. In this burner two steatite arms rising from a common base at right angles led the acetylene to two small orifices exactly opposite each other and giving the double jet. Immediately above the gas orifice a small platinum plate was fixed at a distance of about 0·5 mm. from the steatite, with a hole in it

The principle of the Bill-willer burner

rather larger than the orifice in the steatite just below. The acetylene issuing from the hole in the steatite rushed through the hole in the platinum

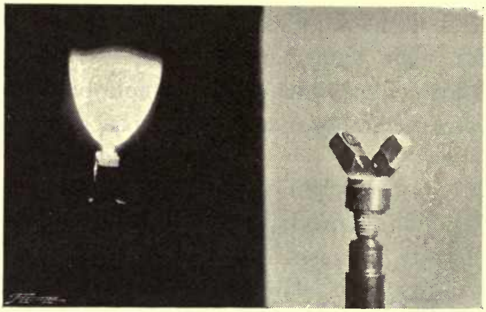


FIG. 183.

above and drew air in under the platinum plate. The air so drawn in flowed to the confines of the rapidly travelling stream of acetylene and passed upwards around it, so preventing contact between the edge of the hole in the platinum and the acetylene, whilst the metal being part of a collar of platinum fixed round each steatite arm, and being a good conductor of heat, prevented such heating as would lead to the deposition of carbon from the gas.

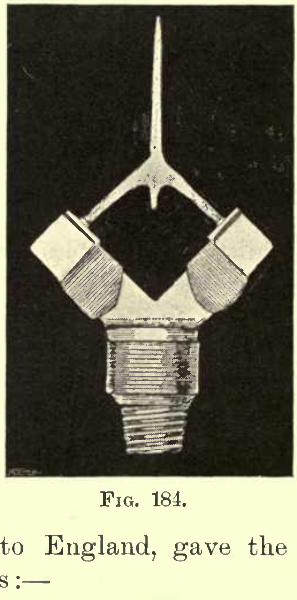


FIG. 184.

These burners, sold under the name of the Basle burner, gave excellent results, and a series of them, tested by the author when they were first introduced into England, gave the following photometric readings:—

The photometric results obtained

Number of burner.	Gas consumed in c. ft.	Pressure in inches of water.	Total light in candles.	Candles per c. ft. of gas.
1	0·35	2·25	4·2	12·0
2	0·625	2·25	19·0	30·4
3	0·75	3·0	24·0	32·0
4	0·90	3·0	32·0	35·5
5	1·00	3·0	36·0	36·0
6	1·00	3·0	40·0	40·0

The author has tested these burners from time to time and has usually found the one foot burners give a duty of from 35 to 40 candles.

Very little, if any, alteration has taken place in their manufacture, some obtained from Schwarz of Nürnberg late in 1899 giving:—

Number of burner.	Gas consumed, c. ft.	Pressure, inches.	Total light, candles.	Candles per c. ft.
1	0·5	2·0	7·0	14.0
2	0·75	2·0	24·0	32·0
3	0·75	2·0	28·0	37·3
4	1·2	3·0	48·0	40·0
5	2·0	3·5	76·0	38·0

The Dolan or Naphey burner

In 1897 Dolan in America made a burner on exactly the same principle as the Billwiller burner, though of slightly different construction. It consists of a metal base, the upright from which forks into two arms which, near their extremities, are bent inwards at right angles. These arms carry steatite or "lava" tips constructed as shown in Fig. 185. The tips are bored with a fine hole from the interior to the base of the mushroom head, where its diameter is more than doubled, whilst four small lateral air tubes are bored at regular intervals

The Naphey tip

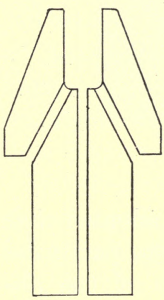


Fig. 185.

from the base of the head to the broad aperture of the nipple, with the result that the flow of acetylene from the narrow into the wider tube sucks air in through the side-tubes and surrounds the ascending

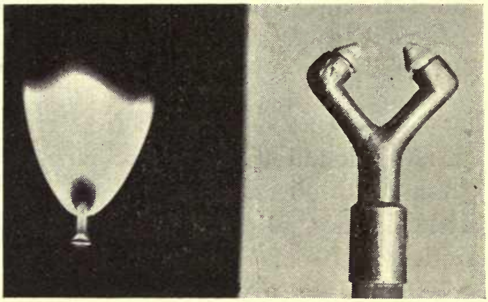


FIG. 186.

gas with an envelope which prevents its contact with the heated tip. These burners, which are more usually known as the "Naphey" burners, gave very

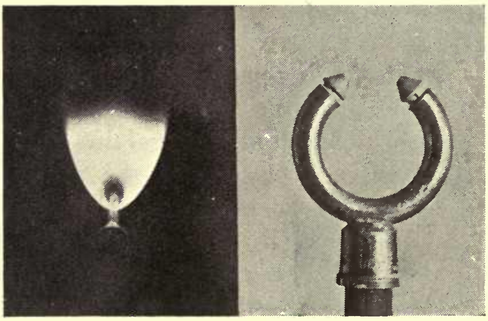


FIG. 187.

good results, and have been more widely adopted than the Billwiller burners that preceded them, partly because they did away with the expense of the platinum, were cheaper to make, and were less liable to

break. A table of the results obtained with this burner is given on page 531.

Variation of the form of mounting

These tips are very largely manufactured on the Continent, both the American and English supply coming from Nürnberg. The form of mounting, however, is considerably varied in order to suit the taste of the user or to give the burner a new name. A very popular form consists of the arms being made as

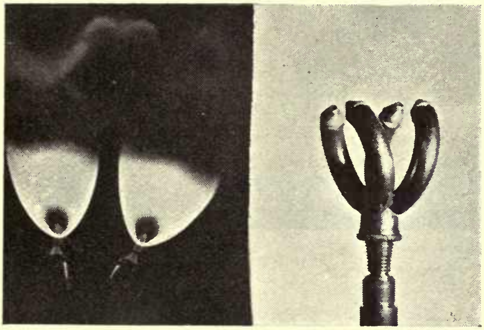


FIG. 188.

a portion of a circle, this modification doing away with the friction and check to the flow of the gas due to the sharp bend in the original pattern, whilst these again are made up in groups of two or three burners where greater illumination is required, as shown in Figs. 188 and 189.

Composite Napheys

This alteration in the shape of the bearing arms has no appreciable effect upon the light emitted by the burner, but in a large installation might make a slight difference in the pressure required to give the best results.

Other forms of Naphey burner

Another common mounting for the Naphey tips is shown in Fig. 190, in which the arms of the burner form a semi-circle ending in small chambers into which the tips are fixed. The small expansion chamber so formed behind each tip is by no means

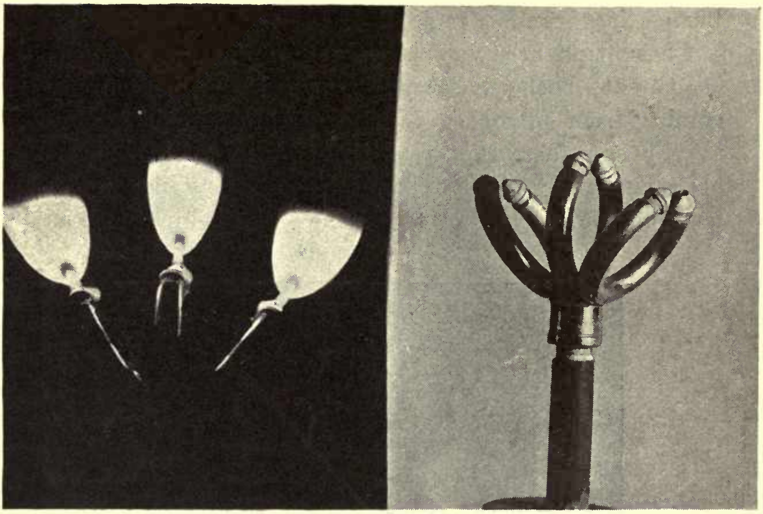


Fig. 189.

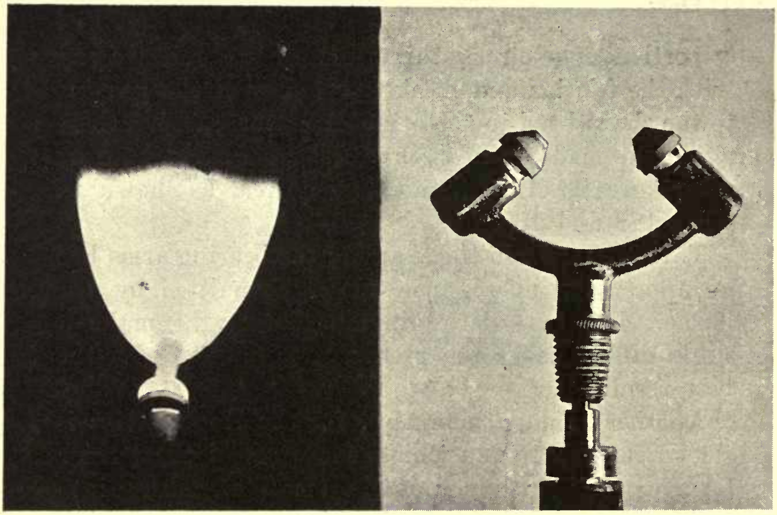


Fig. 190.

a drawback, and these burners generally give a very steady, well-shaped flame.

A burner bearing a strong likeness to the class using Naphey tips is one sold in France and by the Ideal Company in England, in which the same shaped tip is used, but instead of the lateral air-holes, two saw cuts are made at right angles across the tip, dividing it into quadrants down to the base of the head, and through these slits the gas, issuing from the narrow to the broad central tube, sucks the necessary amount of air. The photometric results given by this burner are as follows:— French quadrant tip burner

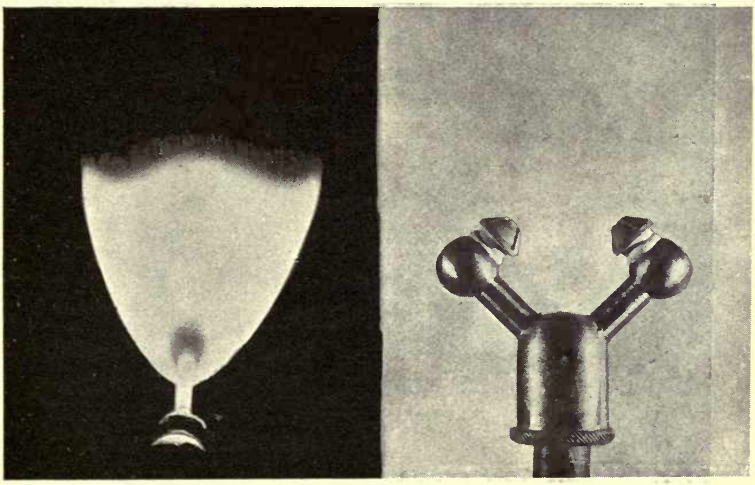


Fig. 191.

Photometric results

Number of burner.	Pressure, inches.	Gas consumed, c. ft.	Total light, candles.	Candles per c. ft.
1	2·5	0·35	4·0	11·4
2	2·5	0·55	15·0	27·27
3	2·5	0·80	28·0	35·0

The great drawback to all the Naphey tip burners is that the heat from the flame causes a slight and gradual warping of the metal mounting, with the Drawback to the Naphey class of burner

result that the jets after a time become slightly thrown out of their true position, which at once distorts the flame and causes it to throw up smoky points.

Attempts to overcome the trouble of warping

This trouble is not found with burners having steatite or composition arms, as these, being pressed or cut, do not warp with the heat, and attempts have been made to obviate this trouble by mounting the Naphey tips at the requisite angle on a bar of steatite, as

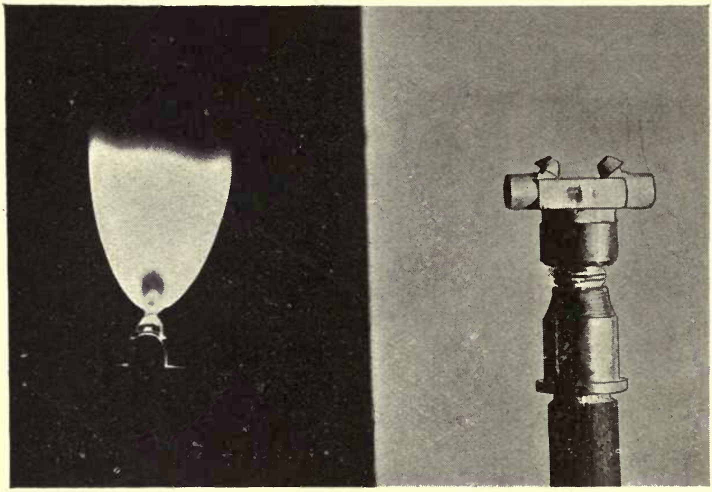


Fig. 192.

shown in Fig. 192; the results given, however, are not as high as with the ordinary form.

The burners most largely used on the Continent are the Napheys and developments of the Billwiller burner, in which the platinum plate is done away with, and other devices for supplying the necessary air adopted.

Developments of the Billwiller class of burners

In the burner shown in Fig. 193, the steatite arms have the same form as in the Billwiller burner, but the air is sucked in through three lateral holes bored at right angles to the gas supply, and discharging into it just before combustion.

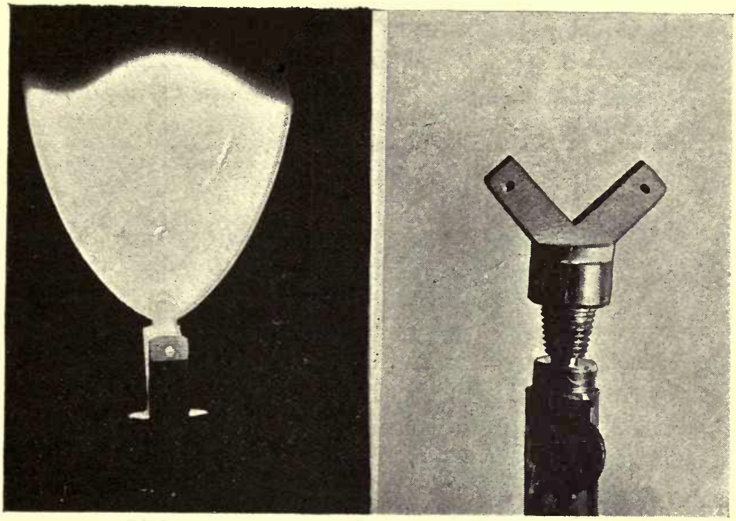


FIG. 193.

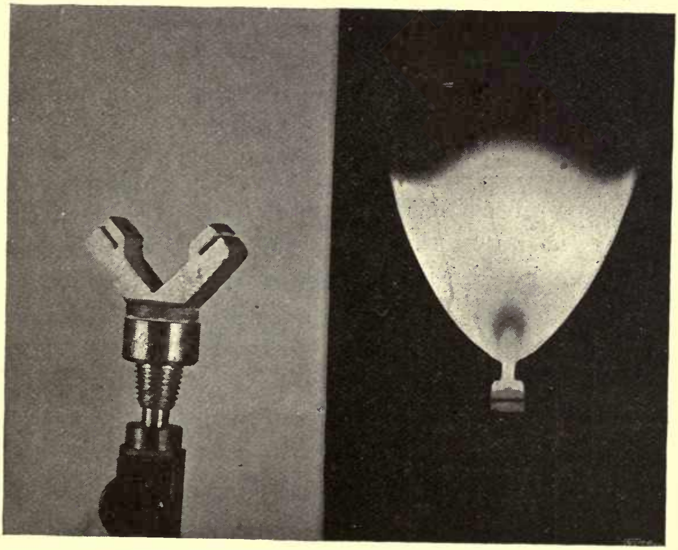


FIG. 194.

This burner gives very good results, the following table giving determinations made with a series:—

Photometric results

Number of burner.	Gas consumed, c. ft.	Pressure in inches.	Total light, candles.	Candles per c. ft.
1	0·35	2	6·0	17·2
1½	0·40	2	10·0	25·0
2	0·55	2	20·0	36·3
3	0·70	2	25·0	35·7
4	0·80	2	34·0	42·5
5	1·0	2	40·0	40·0

Steatite Billwiller burner

Another excellent burner of this class is shown in Fig. 194, and is simply the original Billwiller burner with the platinum plate replaced by one made in steatite or composition. The results obtained with it were:—

Number of burner.	Gas consumed, c. ft.	Pressure in inches.	Total light, candles.	Candles per c. ft.
1	0·4	2·0	2·8	7·0
1½	0·5	2	12·0	24·0
2	0·6	2	20·0	33·0
3	0·75	2	30·0	40·0
4	0·8	2	30·0	37·5
5	1·0	2	36·0	36·0

Other burners of the Billwiller type

A representative of this class of burner, in which the air is drawn through a saw-cut by the issuing gas, is shown in Fig. 195, and the photometric results obtained with it were:—

Photometric results

Number of burner.	Gas consumed, c. ft.	Pressure in inches.	Total light, candles.	Candles per c. ft.
1	0·3	2	5·6	18·6
1½	0·3	2	7·0	23·3
2	0·5	2	18·0	36·0
3	0·75	2	30·0	40·0
4	1·0	2·5	36·0	36·0
5	0·9	2·5	34·0	37·7

The author is perfectly aware that these tests are in many cases far lower than the results claimed, but they represent the results obtained with the burners as they exist on the market, and are published in order to emphasize the fact that in using burners consuming 0·5 c. ft. and under, the light-giving power

The false economy of using too small a burner

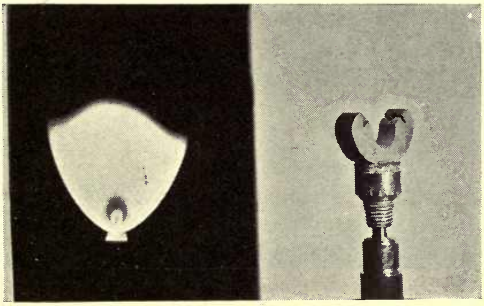


FIG. 195.

of the acetylene is being wasted to a very large extent, and that the most economical burners to use are those consuming 0·75 to 1·0 c. ft. of gas per hour.

Moreover, the difficulties of manufacture with the smaller sizes are so great that uniformity is rarely attained, and the results are most variable.

Schulke burners

In 1896 Schulke introduced a burner in which a cluster of small tubes rose from a common base, the tubes being capped by a nozzle of slightly larger diameter (Fig. 196). These burners gave a cluster of single jets, round which a brisk draught of air was created by the use of a chimney, and when, later, the efficiency of the union of two streams of acetylene was realized, a new and very pretty form of burner was devised by Schulke, and sold by the Hera Company, in which the tubes were forked and bent inwards to cause the jets to impinge upon each other and give a flat flame, whilst the cap had a slight cut

The Hera burners

in its side to allow of the insuck of air by the acetylene.

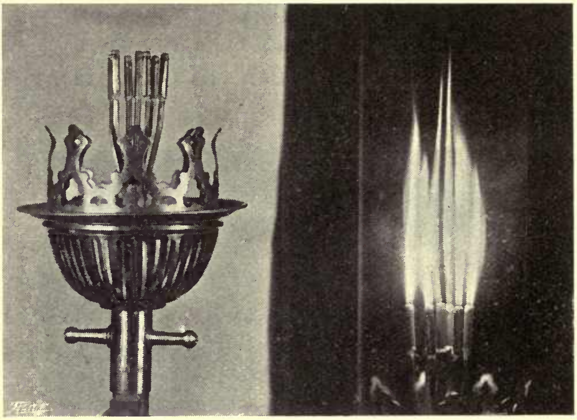


Fig. 196.

Composite Hera burners

These double jets could then be made up in clusters of several pairs, as shown in Figs. 198 and 199, and

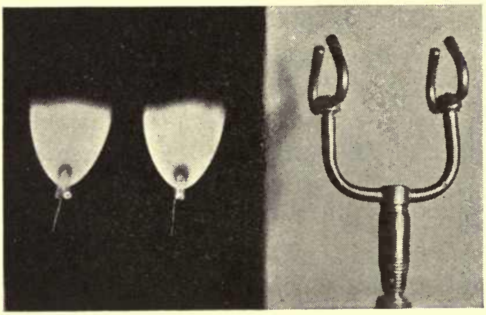


Fig. 197.

gave a very pleasing effect and a duty of about 33 candles per cubic foot of gas.

The "Mushroom" union jet burners

A class of acetylene burner, which can certainly lay no claim to elegance of construction, consists of a big steatite or composition mushroom head, Fig. 200,

with two holes bored near the upper edge and giving the jets which splay themselves out into the flat flame.

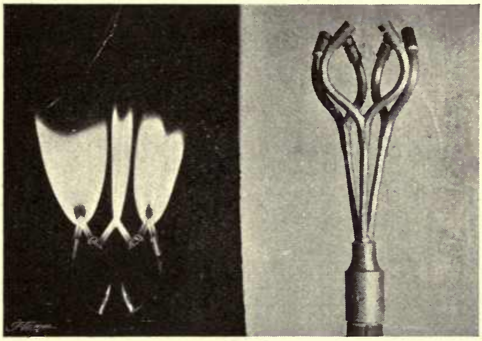


FIG. 198.

In the large burners of this type the top is only slightly hollowed out, but in the smaller sizes a deep dimple is formed in the centre of the burner-top (Fig.

Modifications of this type of burner

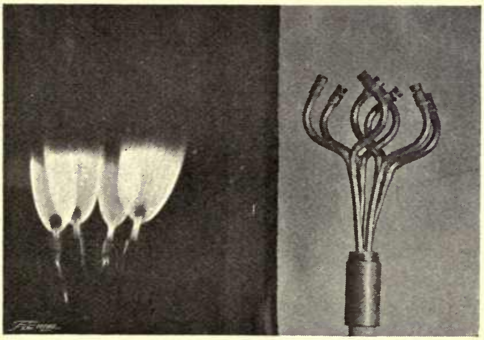


FIG. 199.

201). In a modification of this burner the cavity at the top of the burner is replaced by a clear way to supply air to the base of the flame, whilst the large sizes are arranged for use with a chimney to still further increase the supply of air to the flame.

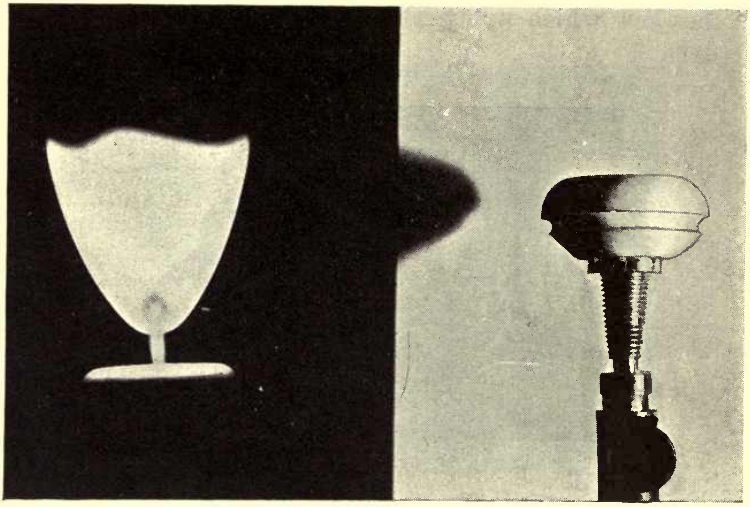


FIG. 200.

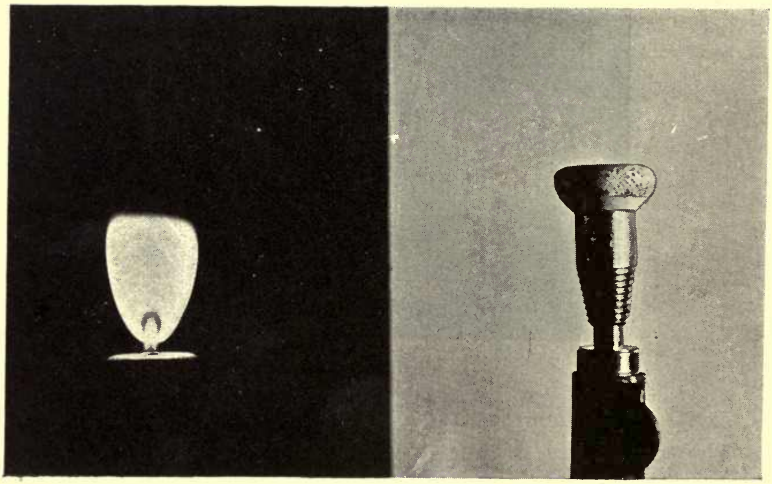


FIG. 201.

The duty given by these burners shows no gain over that obtained by the Billwiller type; no ad-

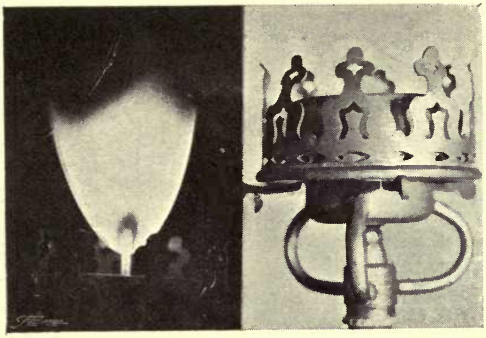


FIG. 202.

mixture of air before burning takes place, and the appearance of the burner is decidedly clumsy.

Same type of burner with air supply to jets

There are also burners of this kind in which, as well as a central air-way, there is a thin steatite plate with openings in it above the exit holes for the acetylene in order to surround the jets with air, as in the case of the Billwiller (Fig. 203). In the smaller sizes of this kind of burner the upper steatite rim is cut away, to give freer access of air to the base of the flame.

Single and multiple jet burners

A large number of single and multiple jet burners are made, both with and without air supply, reminding one of the early days of the coal gas industry, when Murdoch's "cockspur" and "cockscomb" burners paved the way for the introduction of the "batswing" and Neilson's "union jet" burners.

Single jet burners for bicycle lamps

The jet burner in its simplest form consists of a steatite tip pierced at its apex and yielding a single acetylene jet. These burners are largely used in English acetylene cycle lamps, and yield a miserable duty, giving about 6 candles for the consumption of 0·4 cubic foot of acetylene per hour.

Photometric results

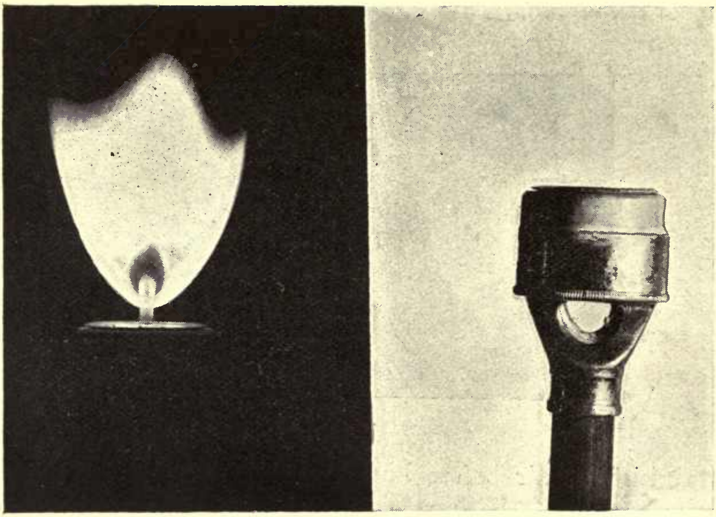


FIG. 203.

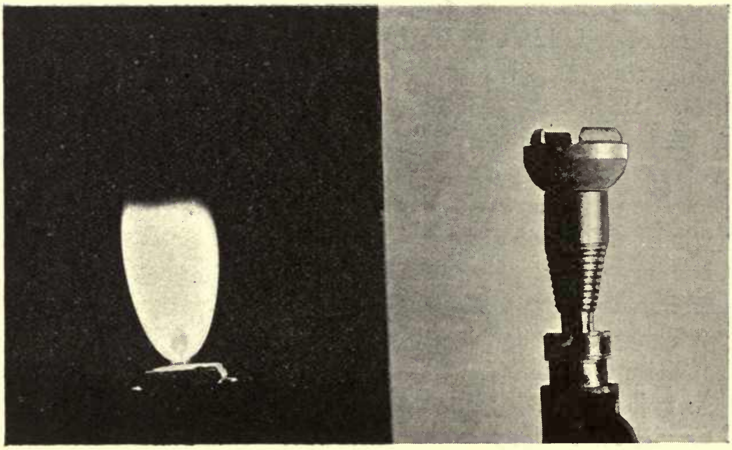


FIG. 204.

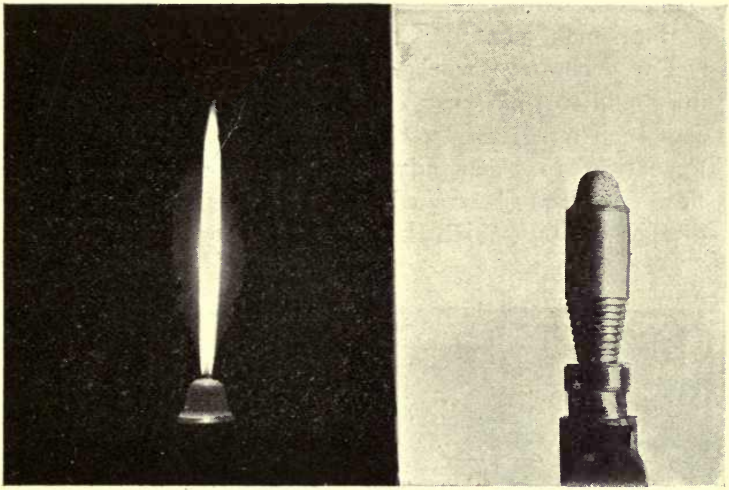


FIG. 205.

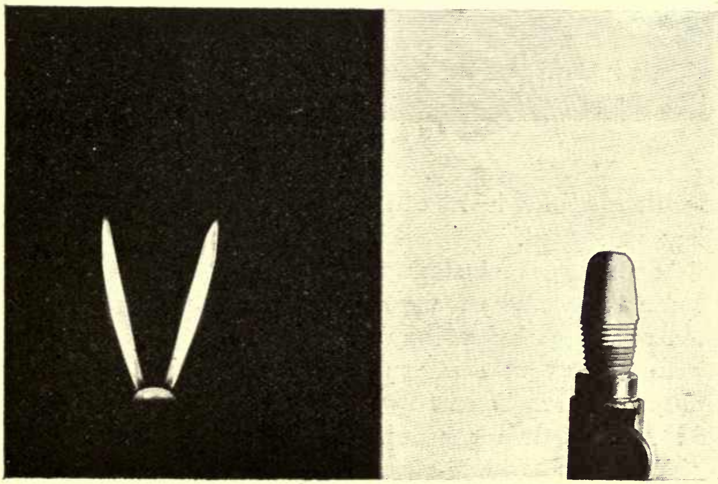


FIG. 206.

Multiple jet burners

A double jet burner of the same type is shown in Fig. 206, whilst Fig. 207 gives a cluster composed of four such jets.

Multiple jet burners for decorative work

For decorative work cluster burners of this kind are made to give very charming effects, a cluster of jets such as given by the nipple shown in Fig. 208 appearing to great advantage when mounted in a flower-shaped glass shade, in spite of the low duty of the burner. With this class of burner the average

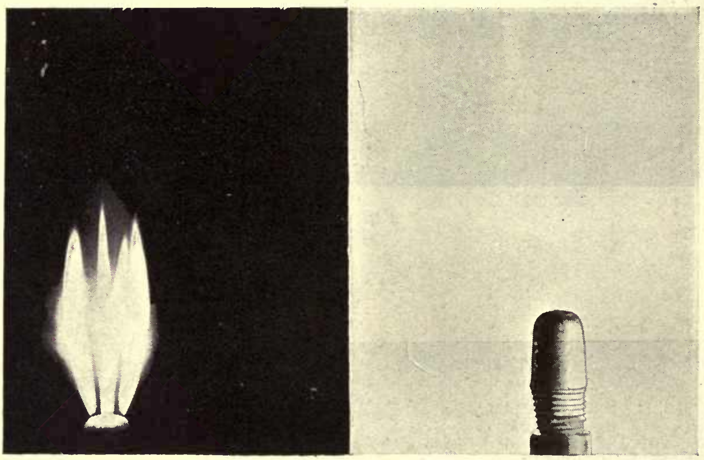


Fig. 207.

result obtained is 16 candles per cubic foot of acetylene consumed.

Aerated multiple jet burners

With larger clusters the burners are sometimes made more like an argand, with air-way down the centre and a double top, to allow air to be drawn in with the jet of acetylene (Fig. 209). This at once raises the duty from 16 to about 27 candles per cubic foot of acetylene consumed.

Cockscomb burner

A very charming effect is produced by the small "cockscomb" burners made on the Schulke principle, Fig. 210, in which a row of small jets, so close to-

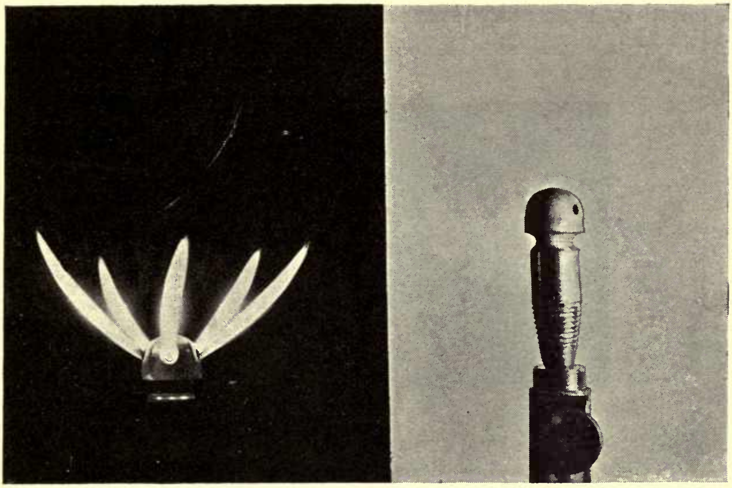


Fig. 208.

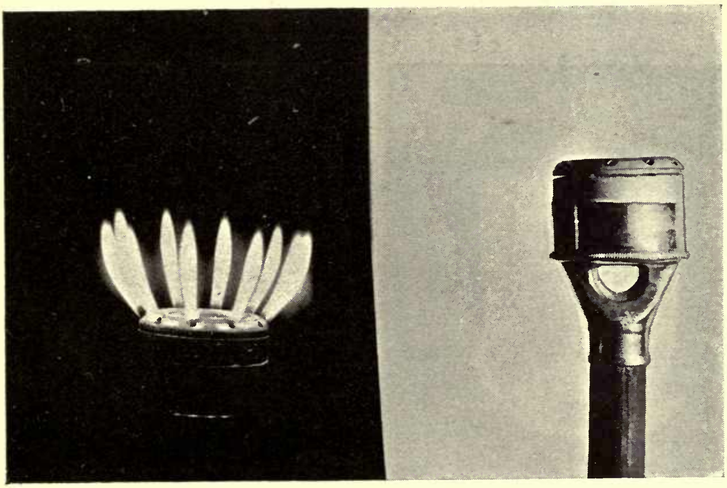


Fig. 209.

gether as to almost allow the flames to coalesce, are bored in a steatite tip, the acetylene drawing in air through small side holes on its passage to the tip.

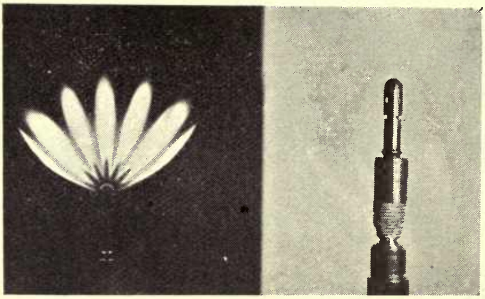


FIG. 210.

Simple "Slit" flatflame burner

There are various types of burner tips, based on both the batswing and union jet patterns. One of the best forms of the slit burner has the tip formed of a steatite ridge, in the centre of which a small slit is cut, whilst of the union jet nipples the ones

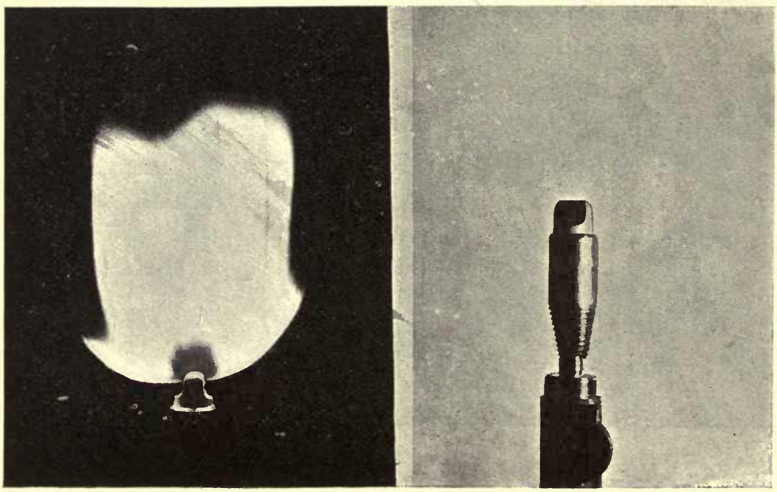


FIG. 211.

German union jet burners

most used for cycle lamps in Germany have the top of the burner brought up to a sharp ridge, in the upper edge of which are the two little union jet holes that give the flame, whilst at the base of the flame two fairly broad holes lead through to the base of the head and conduct air upwards to the bottom of the flame, so as to burn away any carbon deposit which may form at the mouth of the burner.

Air supply below the base of the flame

These burners give a duty of 28 to 30 candles per cubic foot of gas consumed, but are very liable to

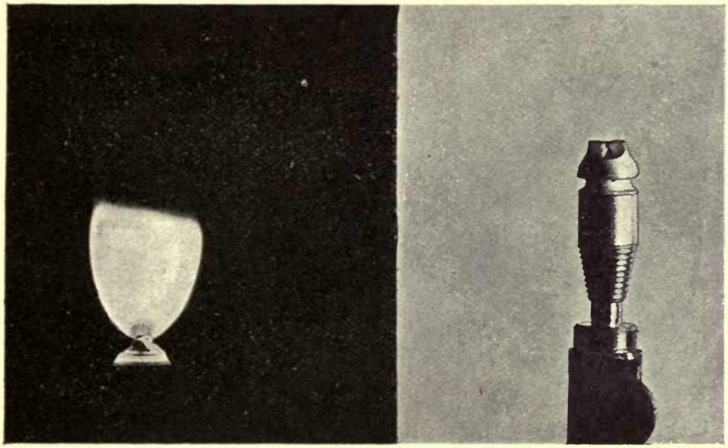


FIG. 212.

smoke; indeed, the principle of surrounding the jet of acetylene with an envelope of air gives practically the only class of burner in which this trouble is to any great extent lessened.

Modification of the Bray burner for Acetylene

It has already been pointed out that the early Bray tips gave very satisfactory results, their drawback being that they never lasted more than a few hundred hours without smoking. Some nipples are now made in which it is attempted to obviate this trouble by making a small boss in the centre of the burner

tip which carries the union jets, instead of a flat top for the union jet to start from, and so increasing slightly the distance between the base of the flame and the body of the tip.

Latest form of flat flame burner

One of the latest forms, Fig. 214, produced consists of a slit burner, above the nipple of which is an arch of steatite carrying a slit of greater dimensions, so that as the sheet of acetylene flows upwards from the original slit of the nipple, it draws in with it through

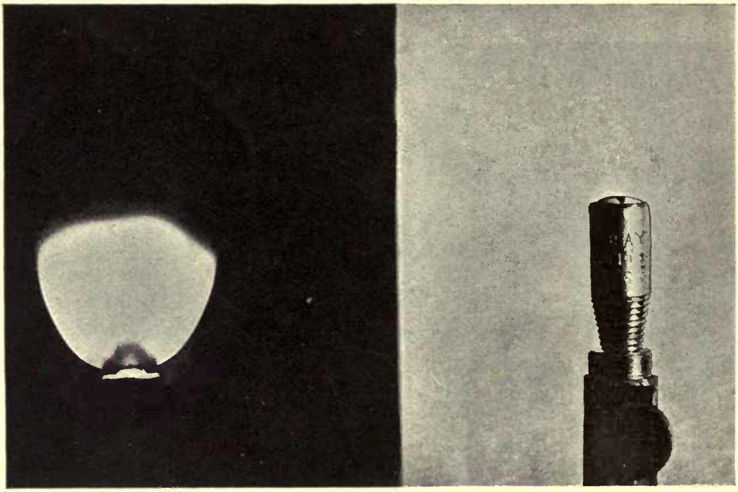


FIG. 213.

the upper slit an envelope of air. A burner of this character, tested by the author, consumed $2\frac{1}{2}$ cubic feet of acetylene per hour at a pressure of $4\frac{1}{2}$ inches, and gave an illuminating value of 115 candles, or 46 candles per cubic foot.

The American "Wonder" burners

A burner of much the same type as the Billwiller class is at present enjoying considerable popularity in America under the name of the "Stewart" or "Epworth Wonder" burner (Fig. 215). It consists of two circular heads fitted to a steatite or composition base,

the jets from which coalesce forming the flat flame. The novelty consists of a deep circular groove cut in

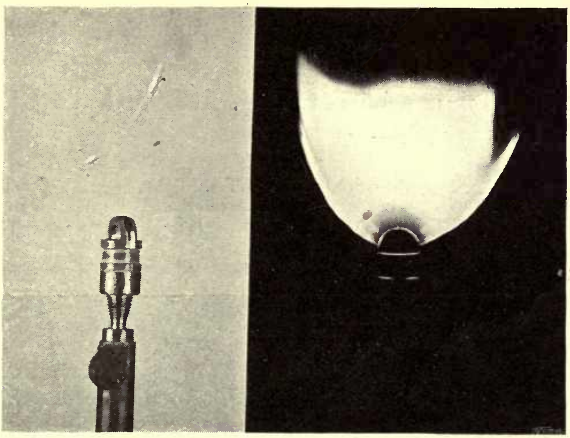


Fig. 214.

the top of the heads, down which the air that surrounds the jet is drawn.

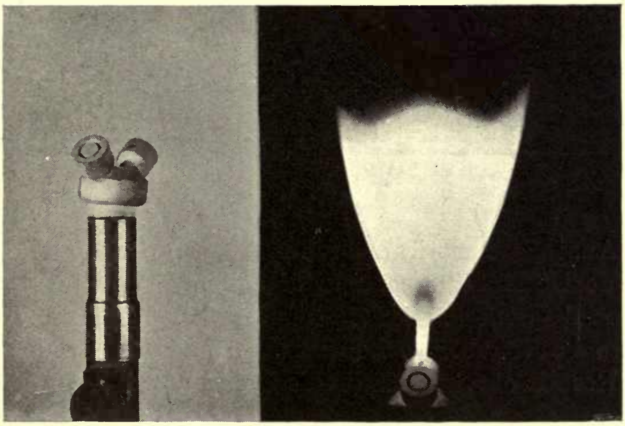


Fig. 215.

Tests made with this burner gave the following results :—

Results obtained with "Wonder" burners

Gas consumed, cubic feet.	Pressure, inches.	Total light, candles.	Candles per cubic foot.
0·7	2·0	16·5	23·5
0·8	2·0	22·0	27·5
1·1	3·0	38·0	34·5
2·0	4·0	64·0	32·0

A double flame burner, Fig. 216, with two jets in each head gave:—

Gas consumed, cubic feet.	Pressure, inches.	Total light, candles.	Candles per cubic foot.
1·6	3·0	60	37·5

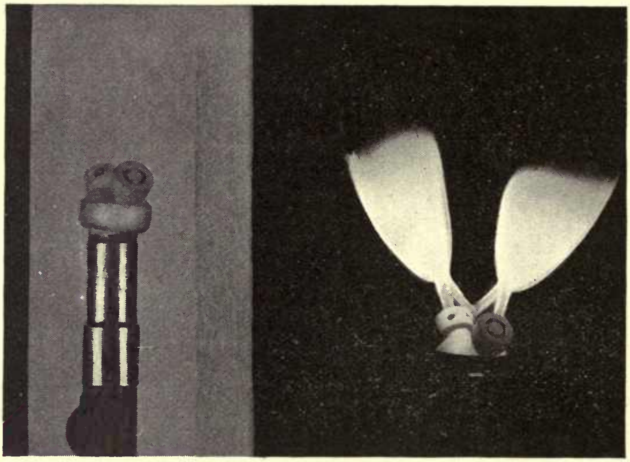


Fig. 216.

The American "Ideal" burner

Another American burner, known locally as the "Ideal," Fig. 217, consists of a double jet mushroom top tube with a series of air-holes drilled from the base into a cavity below the spot where the two jets meet.

Results obtained with this burner were:—

Gas consumed, cubic feet.	Pressure, inches.	Total light, candles.	Candles per cubic foot.
0·75	2·0	22·0	29·33
1·1	2·5	34·0	30·09
1·1	3·0	40·0	36·36

Many attempts have been made to construct good argand burners for acetylene, but they have mostly **Acetylene argands**

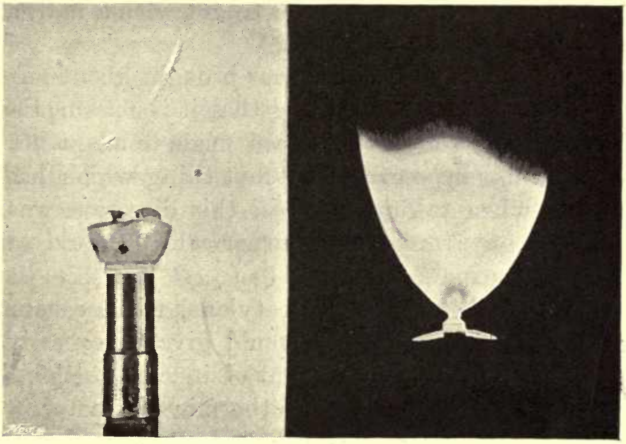


FIG. 217.

been failures, perhaps the most successful being the argand shown in Fig. 218, in which a 20-hole steatite

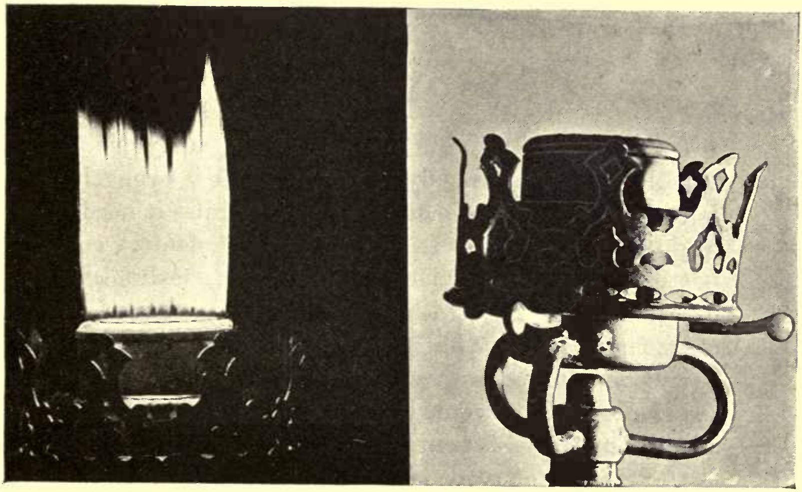


FIG. 218.

argand has a slit round it immediately below the apex through which air is drawn in with the flame, but the duty obtained per cubic foot of acetylene consumed is only the same as can be got with a flat flame burner of the Billwiller type.

Atmospheric Acetylene burners for incandescent mantles

The incandescent mantle has brought about such a revolution in coal gas lighting that it is not surprising that attempts should have been made to adapt acetylene for this purpose, and the first thing which had to be done when taking steps in this direction was to construct an atmospheric burner which would satisfactorily consume the gas.

Heat of the flame of the atmospheric Acetylene burner

One would expect that acetylene, when consumed in an atmospheric burner, would give an excessively hot flame, not only on account of its composition, but also on account of its endothermic character. Le Chatelier calculates that the temperature of a non-luminous acetylene flame will range from 2,100° to 2,420° C., the temperature varying with the ratio of acetylene to air as shown in the following calculations:—

Le Chatelier's calculations of the temperature of the flame

Percentage of Acetylene.	Percentage of Air.	Temperature. °C.
7·4	92·6	2,420
12·9	87·1	2,260
17·37	82·63	2,100

The difficulties found in making an Acetylene Bunsen

In order to make a Bunsen burner for acetylene the tube has to be extremely narrow, and it is even then found to be very liable to flash back, whilst it needs a high pressure in order to bring about satisfactory combustion of the gas with an absolutely non-luminous flame. One of the chief difficulties which have to be overcome is due to the range over which mixtures of acetylene and air are explosive. This lies between the limits of 3 per cent. and 82 per cent. of acetylene, and it must also be remembered that the velocity of the explosion of acetylene when mixed with air is greater than with a mixture of air and coal gas, and

the propagation of the explosive wave down the burner tube cannot be satisfactorily stopped by the ordinary device of using wire gauze, on account of the low igniting point of acetylene and air mixtures. If high pressures are used so that the rate of flow shall be greater than the velocity of propagation downwards, more air is sucked in by the uprush of the gas, and the velocity of the explosion is again increased.

Velocity of explosion of the mixture in the burner tube

The best results have been obtained by taking a Bunsen burner, in which a constriction in the air tube creates a high velocity at that point, which, on the principle of the Smithell's flame separator, prevents the propagation downwards.

The method by which the best results are obtained

Le Chatelier has shown that the rate of propagation of an explosive mixture of air and acetylene depends upon the diameter of the tube through which the wave is being propagated, and he has worked out the limits between which the explosive wave would pass through tubes of certain diameters.

Diameter of tubes that will stop the explosive wave

Diameter of Tube.	Explosion.	
Inches.	Lower Limit, Per cent. Acetylene.	Upper Limit, Per cent. Acetylene.
1·57	2·9	64
1·18	3·1	62
0·79	3·5	55
0·24	4·0	40
0·16	4·5	25
0·08	5·0	15
0·03	7·7	10
0·02	0·0	0

It will be seen that in a tube 0·02 inch or ·5 m. in diameter you have the propagation of the explosive wave ceasing.

These investigations have been used as a basis upon which to construct acetylene burners for heating purposes, and burners have been made by the Allege-

Construction of the existing burners for incandescent mantles

meine Carbid und Acetylen Gas Company of Berlin, in which, by means of constricted tubes, satisfactory consumption is ensured. It is found that the diameter of the tube at the constriction must be in a definite proportion to the particular mixture of air and acetylene consumed, as the more air employed the greater must be the constriction in the strangulated portion of the tube. Such burners have a flame which is very valuable for heating purposes, and gives a very intense temperature.

Results obtained with mantles

With a large Bunsen made for incandescent mantle lighting by the above firm, and employing a large sized Welsbach mantle, the author has obtained 448 candles for a consumption of 4·6 cubic feet of acetylene per hour, a duty of 96 candles per foot, whilst with a smaller acetylene Bunsen used by the Turr Acetylene Company 90 candles per foot were obtained, so that it may be roughly stated that acetylene will yield rather more than double the amount of light when used with the incandescent mantle that it will when burnt by itself under the best possible conditions.

It must be clearly borne in mind, however, that in all probability the life of the mantle would be very seriously shortened by the temperature to which it is exposed, whilst the tendency that acetylene Bunsens have of firing back with a sharp explosion also exposes the mantle to a far greater risk than is the case with coal gas.

Importance of complete purification of the gas when used for heating mantles or platinum vessels

Should any great progress ever be made with incandescent lighting by means of acetylene, it will be found that very careful purification of the gas is an absolute necessity, as any trace of phosphuretted hydrogen in the acetylene will cause the formation on the surface of the mantle of phosphates of the earths employed, which, being readily fusible, bring the life of the mantle to an abrupt termination. This point is also well to remember in connection with atmo-

spheric acetylene burners made for heating purposes. The author knows of several cases in which attempts have been made to utilise acetylene for work in private chemical laboratories where coal gas is not available, and platinum vessels heated in the acetylene flame are rapidly destroyed owing to the phosphorous compounds in the original gas.

Domestic illumination is so important a factor in most of our households that it might be expected that a fairly general knowledge would exist as to the principles upon which efficient illumination depends, and yet there are few subjects upon which cruder and more erroneous ideas are to be found, not only amongst the general public, but even amongst many who are supposed to have made a special study of the questions involved.

Illuminating power

When, about the middle of this century, the Legislature began to attempt to safeguard the consumers of coal gas, it was done by prescribing a certain standard of illuminating value to the gas, this being determined by the photometric methods then in vogue. This value was called the illuminating power of the gas, and up to a few years ago was looked upon by most people as expressing the amount of illumination to be obtained under ordinary circumstances from the gas.

This assumption, however, is far from correct, and has given rise to a chaotic bemuddlement in the theory and practice of illumination.

Illuminating power and illuminating effect

During the past five years it has been gradually realised by many that illuminating power and illuminating effect mean two totally different things, and this apparent anomaly depends upon several distinct factors. In the first place, illuminating power, or illuminating value, is merely a technical method of expressing the ratio of light emitted by the combustion of a certain sample of gas as compared with

the light of the standard employed, and has but little to do with the effect produced when the gas is consumed under conditions differing from those under which it was tested.

What is meant by illuminating power

Indeed, where the consumer has taken the trouble to find out what is meant by the statement that he is supplied with a 16 candle power gas, he learns that it means that, when the gas is burnt at the rate of 5 cubic feet an hour in the London argand, it emits a light equal to 16 candles, each consuming the sperm at the rate of 120 grains per hour. He assumes, therefore, that by burning his gas at the rate of 5 cubic feet an hour in the London argand, he gets the same illuminating effect in his room as if he had utilised the 16 sperm candles.

Superiority of distributed over concentrated centres of light

Observation, however, would soon convince him that this is not by any means the case, and that if he distributes his 16 sperm candles judiciously in his room, the illuminating effect produced is far superior to the London argand emitting the same amount of light from a gas bracket in the centre of the room; and this simple instance strikes the keynote of the difference existing between illuminating power and illuminating effect.

The importance of avoiding strong contrasts

In the one case you have 16 centres of light, each illuminating a certain portion of the room, and none of them sufficiently intense to form a contrast with the others; whilst with the argand, emitting its 16 candles of light from one small cylinder of flame, you have an area of brightness in the centre of the room which throws the surrounding portions into comparative darkness, although they may be illuminated to an extent which, without the brilliant contrast, would appear sufficient and satisfactory.

The drawback of small and intense

The greater the intensity of the flame, *i.e.* the smaller and therefore brighter the surface from which the light is emitted, the more difficult does it becomes

to avoid such contrast, and the wonderful intensity of the acetylene flame, which makes it so valuable an illuminant, also gives rise to the necessity for careful treatment as regards distribution in order to obtain the best illuminating effect.

sources of light

Illuminating power only expresses the value of the horizontal rays

In considering the illuminating power of acetylene, it must also be borne in mind that the photometer only measures the relative intensity of the direct rays emitted by the flame, every precaution being taken to shut off reflected light; whilst in the lighting of a room the light reflected from the walls and ceiling plays a very important part, and the amount of light reflected by the object on which it falls will also vary with the angle at which the rays strike the object.

Reasons for the recorded illuminating value not being a true index of the result obtained

The result of this is that, although the values recorded by the photometer give a ratio of value for the direct rays falling in the same horizontal plane as the source of light, they tell us nothing as to the combined value of the direct and diffused light cast upon our book or any working surface, which, as a rule, will be at angles varying from 45° to 90° below the flame.

The direct rays are those which, radiated from the luminous source, fall directly on the object illuminated, whilst diffused light consists of those rays which have been reflected from one or more surfaces, or which have been refracted by passage through media of varying density; and as photometry only deals with the primary source of illumination, and that, as a rule, only on the horizontal plane, it is absurd to suppose that such recorded illuminating results can have any value as indications of the illuminating effect arrived at in practice.

The light yielded at angles below the horizontal the important factor

In an ordinary dwelling-room the gas lights are, with very few exceptions, so arranged as to be above the line of sight, and so avoid irritating the eye; and a moment's observation will convince any one that the

illumination shed upon our book or writing is derived from a source at from 40° to 90° above it, and it is manifestly the illumination given by the burner between these angles which is the important factor in domestic lighting.

Illuminating Value of Coal-gas and Acetylene at angles below the Horizontal, in terms of Candles per Cubic Foot.

Results obtained with various burners at lights below the horizontal

Angle.	Coal gas. London Argand.	Union jet No. 5	Union jet No. 7	Batswing No. 5	Batswing No. 7	Incandescent.	Acetylene 1 foot (Billwiller burner).
Horiz.	3·2	1·67	2·09	1·90	2·43	16·6	40·0
10	3·19	1·67	2·08	1·84	2·42	16·6	40·0
20	3·07	1·55	2·03	1·73	2·38	16·1	40·0
30	2·72	1·45	1·88	1·61	2·25	11·1	38·0
40	2·38	1·40	1·64	1·47	2·18	8·8	38·0
45	2·18	1·30	1·50	1·38	2·12	8·0	36·0
50	2·12	1·27	1·50	1·38	2·05	6·6	36·0
60	1·20	1·23	1·50	1·30	2·07	2·0	30·0
70	unreadable	1·23	1·37	1·23	2·00	unreadable	26·0
80	"	0·76	1·25	0·76	1·75	"	20·0
90	"	0·30	0·87	0·76	1·37	"	5·0

The advantage of flat flame over argand burners

On now turning to the table showing the results given by various burners at angles from the horizontal down to 90°, the inferiority of the standard London argand at once becomes apparent, as at an angle of 60° it is surpassed in illuminating value by even the small flat flame burner, and the rule of thumb practice, which has made the flat flame burner the popular method of illumination, is fully justified; whilst when we come to high power lights, such as the incandescent and the acetylene flame, we find that the flat flame acetylene burner shows a very marked superiority over its incandescent rival at all the working angles.

Reflection of light from the walls and ceiling of a room plays an important part in adding to the illuminating effect; and whilst with an illuminant of low intensity, such as coal-gas, this is only a small amount, with a flame of high intensity the increase in illuminating effect becomes very great in the downward direction, owing to reflection from the white ceiling.

The importance of reflection in illuminating effect

This is one of the chief causes also of the discrepancies existing between illuminating power and illuminating effect; but other factors less easy to deal with are: the difference in effect caused by the variation in the size of the source of light; the effect of distribution and intensity of the source of light on the visual organs, and the reflecting power of the surrounding objects.

The causes which lead to the discrepancies between illuminating power and effect

The size of the source of light has an important influence on the illuminating effect. If a large flat coal-gas flame and a small acetylene flame of the same illuminating power be placed at equal distances from a rod, and the shadows of the rod be then received on a white screen placed at some distance from the rod, the shadow due to the large flame will be seen to have soft undefined edges, whilst the shadow from the small flame will be sharp and hard; so that, although in each case the depth of shadow may be equal, the one will be far less striking to the eye than the other, and this causes the illuminating effect of the large flame to be better than that given by the small flame. Another important point is that the larger the surface from which a given amount of light is being emitted, the less will be its intensity for any given area, and the less the deadening and irritating effect upon the optic nerve.

The influence of the size of the source of light upon the shadows formed by it

The smaller and more intense the light-emitting source, the greater will be the contrast between the highly-illuminated area immediately surrounding it

The effect of intensity in making contrasts

and the less well-illuminated portions of the room at a greater distance from the source of light, which to the eye, fatigued by the intensity of the central illumination, appears almost in darkness.

Illuminating effect not being due to any one factor acting alone, but the combined effect of at least four, one or more of which vary with the particular environment as well as with the source of light, can only be measured where it is produced, and no calculations can give even an approximation as to the result.

The use of globes in aiding distribution and saving the eyes

In order to as far as possible counteract the injury and discomfort caused to the eye by intense centres of illumination, it becomes necessary to use globes to obtain a better distribution of the light and at the same time a protection to the eye; but in gaining this advantage a considerable sacrifice is generally made in light. For ordinary purposes ground glass, opal, or frosted globes are used, whilst in many houses these globes are made in pink-tinted glass to as far as possible neutralise the ghastly effect which the Welsbach light gives to the complexion. With all such globes the loss of illumination is considerable, and the diffusion of the light far from satisfactory; but a diffusion globe has been introduced based on an entirely different principle, and which, with our present tendency towards small centres of high intensity, becomes simply invaluable.

Diffusion globes

These globes, designed by Psarondatri and Blondel, and introduced under the name of Holophane globes, give us the power not only of correcting the irregular distribution of light, and bringing the maxima of rays down to the working angles, but also make the surface of the globe the light-distributing medium, and so avoiding fatigue to the eye.

In order to do this the globe is made of clear glass, so moulded that the exterior consists of horizontal lines of prismatic form running round the globe,

whilst the interior is covered by vertical lines of prisms running from the top to the bottom.

If the globe had only the horizontal prisms round it, the source of light in the centre of the globe would appear as a vertical band of light, as is seen in the Fredureau globe; whilst if the vertical prisms only were present, the light would be drawn into a horizontal band in the same plane as the mantle, but the combination of the two draws the light evenly over the whole surface of the globe.

The construction of diffusion globes

The horizontal prisms are so moulded as to deflect downwards the excess of light otherwise escaping upwards, thus giving an increase in illuminating power over the working angles, whilst the large surface of emission makes the light pleasant instead of irritating to the eye.

Comparisons between various globes

In order to ascertain how these globes compared with those most generally used, a long series of tests was made on the radial photometer as to the absolute gain or loss in direct illumination afforded by their use.

Methods of experiment

In making these experiments, five observations were taken with the unshaded flame, then ten with the shade that was under trial, and immediately after five more with the unshaded burner, so that for each globe a separate set of ten observations with the unshaded, as well as the shaded light were obtained, and the percentage loss or gain calculated from the average results. Observations having in this way been made for the angles below the horizontal, the results indicate the absolute gain or loss due to the shade or globe at that angle. It would be unnecessary and, indeed, confusing to give the enormous mass of figures obtained in this .way, and the following table gives a summary of the mean loss or gain in light due to the globes used at angles between the horizontal and 45° below it.

The results not only show the great gain which is obtained by the use of the Holophane globes, but also bring out in the clearest possible way the serious loss of light involved by the use of pink-tinted globes and shades.

Summary of the results obtained

PERCENTAGE GAIN OR LOSS OF LIGHT FROM THE HORIZONTAL TO 45° BELOW, DUE TO USING VARIOUS GLOBES.

Globe.	Percentage gain or loss in light.
Holophane—tulip shape . . .	gain of 12·3 per cent.
Holophane—conical . . .	„ 13·1 „
Holophane—conical, pink . .	„ 1·1 „
White opal globe	loss of 7·5 „
Ground glass globe	„ 12·4 „
Frosted glass—tulip . . .	„ 11·2 „
Frosted glass—pink . . .	„ 23·2 „
Pink opal globe	„ 34·1 „

Action of the Holophane globes

It must not be supposed for one moment that these figures impute a power of creating light to the Holophane globes. If the light emitted in every direction be taken, a small total loss would be found due to the absorption of some light by the glass, but the angles at which the upper prisms are set deflect downwards some of the rays which otherwise would be expended on the cornices.

Advantages gained by the use of diffusion globes

The more uniform distribution of light taking place from a far larger surface than the original source does away with sharp shadows and the glaring contrast between the source of high intensity and the objects illuminated by it.

The action of opal and ground glass globes on the light

Interesting experiments have been made by several observers, which seem to show that if the diffused light thrown by opal and ground glass shades be measured as well as the direct illumination, the loss of light due to them is not as great as used to be supposed; and Scott deduces from his experiments the fact that clear glass globes cut off 6 per cent. of total light, whilst flash coated globes are responsible for a

loss of 11 per cent., figures which agree very well with those in the above table. In other words, in order to gain any true idea of illuminating effect you must take the light emitted over all the working angles and not in the horizontal plane.

The effect of fog, mist, or smoke in the air upon illuminants

Observation shows us that as long as the atmosphere is sufficiently clear to enable us to see the sun or moon apparently white, but little difference can be noticed in the penetrating power of our outdoor illuminants; but as soon as the sun or moon begins to show a yellow or reddish tint, we immediately begin to notice that the arc light or the Welsbach incandescent mantle begin to fade far more rapidly than the acetylene or ordinary gas lights, and that even in the thickest fog the gas flame, oil lamp, or even candle, seem able to battle more successfully with the atmospheric conditions than their more pretentious rivals.

Although this is perfectly clear to the eye, as far as the author knows, no attempt has been made to ascertain the ratio of the percentage of light so absorbed amongst our ordinary illuminants themselves, although Professor Tyndall's beautiful work on lighthouse illuminants shows clearly the differences which exist in this respect between the electric light and the light due to gaseous flames.

The explanation given of the yellowish-red effect produced by fog or smoke

The explanation of the yellowish-red appearance seen during a fog is that it is caused by the filtration of the light rays through the minute particles of which the fog largely consists; and the same effect is produced when the sun is seen through smoke. The colours in the spectrum are produced by variations in the wave lengths, the difference from crest to crest of the red rays being large as compared with the wave lengths which give the blue-violet end of the spectrum; and the gradual decrease in the distance between the crests is found to take place from the red rays down to the ultra-violet, and when the bundle of

mixed rays which we call white light comes to penetrate the finely divided mass of particles contained in the atmosphere during foggy weather, the small and rapid waves of the blue and violet become checked and absorbed, whilst the waves of greater amplitude are able to find their way through the obstructions, the result being that the light which reaches our eye, being bereft of a large proportion at any rate of the blue and violet rays, has a preponderance of the light from the other end of the spectrum, and therefore appears red or orange, according to the thickness of the layer through which it has passed.

The filtration of the waves of light by the particles in the air

Experimental method of showing this result

A very beautiful way of showing this is to cause the horizontal rays from an electric lantern to pass through a cell containing a dilute solution of sodium hyposulphite, when a white disc is formed on the screen. On now adding some hydrochloric acid to the hyposulphite, a gradual separation of particles of sulphur takes place, and forms a cloud in the liquid, and this behaving in the same way as the solid particles suspended in the fog, the disc of white light is seen to go through the changes of colour so familiar to Londoners during the fall of the year.

Attempts to determine the penetrative power of various illuminants

The author has attempted to utilise a modification of this experiment in order to determine the power of penetrating fog which our illuminants possess, and to do so constructed a glass cell 18 inches deep by 18 inches wide by 3 inches thick. It was filled with a solution containing 0·1075 grammes of sodium hyposulphite to the litre. The illuminating power of the light source to be tested was first read on the photometer in the ordinary way, and the cell containing the clear liquid was then interposed halfway between the source of light and the screen, and a second reading was then taken, the difference between the two giving the light cut off by the cell and the liquid which it contained. ·05 grammes of hydrochloric acid

per litre was then added to the liquid, and the solution was allowed to stand until the fine haze of sulphur particles which separated from the hyposulphite had finished forming, experiments showing that this took some time, but that, owing to the extremely fine state of division of the particles, the haze would remain constant, when once formed, over a very long period. When the haze had completely formed, another reading was taken, and from the three figures so obtained, it was possible to deduce the amount of light absorption due to the haze in the liquid as apart from the absorption of the cell and the liquid which it contained.

Methods of experiment

Working in this way with the greatest possible care, it was found that considerably less light was absorbed from the yellow coal-gas flame than from the whiter acetylene flame, whilst the absorption of the greenish-blue Welsbach mantle was very great indeed, as is shown by the following table:—

PERCENTAGE LOSS OF LIGHT FROM VARIOUS ILLUMINANTS IN PASSING THROUGH ARTIFICIAL FOG SOLUTION.

Loss of light in passage through an opalescent solution

Coal gas flames	11·1
Oil gas flames	11·5
Acetylene flames	14·7
Welsbach mantle	20·8
Electric arc	26·2

which means the acetylene suffers to the extent of 32 per cent. and the Welsbach burner loses 87·3 per cent. more of its light-giving power than the coal-gas flame.

The character of the light emitted by Acetylene

As soon as the possibility of burning acetylene alone had been recognised, the pure whiteness of the flame at once suggested that the light emitted must be closely akin to sunlight in the proportion of the various coloured rays of the spectrum. Munsterberg has published the following table, in which the proportion of each colour that is present in the spectrum of the various lights used for artificial illumination

is contrasted with the amount in sunlight taken as unity.

Table contrasting the characteristics of various illuminants

Colour in spectrum.	Electricity.		Coal gas.		Acetylene.		Sun.
	Arc.	Incandescent.	Ordinary.	Welsbach.	Alone.	With air.	
Red . .	2·09	1·48	4·07	0·37	1·83	1·03	1
Yellow.	1·00	1·00	1·00	0·90	1·02	1·02	1
Green .	0·99	0·62	0·47	4·30	0·76	0·71	1
Blue. .	0·87	0·91	1·27	0·74	1·94	1·46	1
Violet .	1·03	0·17	0·15	0·83	1·07	1·07	1

From this it is evident that the light yielded by acetylene not only more nearly approaches sunlight in the proportion of the rays of different wave length, but is even richer than sunlight in those blue and violet rays which are so essential to the chemical action of light.

Erdmann's researches on the character of the light from the Acetylene flame

Erdmann has done much work on the character of the light emitted by the acetylene flame. Comparing the flame of acetylene from a small union jet burner with holes for the ingress of air, consuming 0·25 cubic foot per hour under a pressure of 28–10ths, with the flame of an Elster's porcelain argand burner consuming coal gas under a constant pressure of 3–10ths, he found that the coal gas flame was relatively deficient in the rays of medium wave length. It is these rays which make it possible to differentiate precisely between shades of colour. The Welsbach light more nearly resembles the acetylene light in this respect, but it exhibits a preponderance of violet rays which disturb the eyes. The acetylene light is an excellent substitute for daylight in spectro-photometric researches. Owing to the inconstancy of daylight, the Hefner light had commonly been used as a standard light in such researches, although it was deeply yellowish-brown in colour. Erdmann points out that

Acetylene as a standard of light

Violle and Féry had already proposed that acetylene should be used as a standard light, and Féry had made a number of observations on the effect of variations in the height of the acetylene flame on the light emitted, and Erdmann also comes to the conclusion that acetylene would furnish an excellent standard of light. As a standard burner for use in photometry, he employed simply a thermometer tube, cut off smoothly at the end, about 6 inches in length, and nearly 0·02 inch—0·5 mm.—in diameter internally. The flame was maintained at a constant height, say, 0·8 inch—20 mm.—and in the first place the light was carefully compared with a Hefner lamp. Such a standard burner consumed only about 0·14 c. ft. of acetylene per hour, but it was essential that the acetylene consumed should be produced, without the prevalence of high temperature, from as nearly as possible pure carbide. In the experiments, carbide from the Bitterfeld works was used, which yielded acetylene almost wholly free from phosphuretted hydrogen.

Erdmann's methods of experiment

Erdmann compared the light from coal-gas with that from such acetylene burnt in two small burners, and with the Hefner unit, and taking the acetylene flame and the Hefner light as the unit in turn, he obtained the following values for the radiation at various parts of the spectrum:—

Results obtained

Colour.	Value when Acetylene=1·00. Hefner Light.	Coal gas. Argand.	Coal gas. Incandescent.	Value when Hefner light=1·00. Acetylene.	Coal gas. Argand.	Coal gas. Incandescent.
Red . .	1·45	1·34	1·03	0·69	0·92	0·71
Orange .	1·22	1·13	1·00	0·82	0·93	0·82
Yellow .	1·00	1·00	1·00	1·00	1·00	1·00
Green . .	0·87	0·93	0·86	1·15	1·07	0·99
Blue . .	0·72	1·27	0·92	1·38	1·75	1·27
Violet . .	0·77	1·35	1·73	1·30	1·75	2·25

Erdmann, in concluding, expresses the hope that physicists would discard the objectionable Hefner lamp in favour of an acetylene standard burner in their ordinary photometrical work.

Hartman on the colour properties of diluted Acetylene flames

In America Hartman has studied the light and colour properties of the acetylene flame and the flame given by mixtures of acetylene and hydrogen, and comes to the conclusion that the acetylene-hydrogen flame is richer in the short wave lengths than the flame of acetylene alone, and he, like Erdmann, is struck by the advantages offered by acetylene as a standard for the measurement of light.

This is not to be wondered at when the unsatisfactory condition of our present standards is considered.

Standards of light

The candle has been recognised as the legal standard ever since its introduction by Bouguer as a unit of light, but the results which are obtained from it in practice do not in any way attain the scientific accuracy which ought to prevail, and whilst the standard does not yield accurate results, it is of little avail to try and obtain perfection in the remaining portions of the apparatus used for testing the quality of light. Wax candles were first enacted to be employed for gas-testing in 1850, before which date there had been no definition as to what candles were to be used, but in 1866 these gave way to sperm candles of six to the pound and burning 120 grains of sperm each per hour, and the light yielded by these candles was a little more than that obtained from the previous wax candles—fourteen sperm candles being equal to sixteen wax ones. Pure spermaceti, owing to its crystalline character and consequent brittleness, could not be used alone in practice, and accordingly the sperm was mixed with 4 to 5 per cent. of beeswax, and great care has to be taken to get the quality of the sperm and the proportion of the mixture uniform. The wick is,

The standard candle

however, the weakest point; a slight variation in the roughness or texture of the material, in the preliminary treatment of the fibre, or the twist of the thread, or the tension during plating, causes great alterations in the light emitted by the candle.

Imperfections of the candle as a unit

All the various committees that have been appointed to consider the question of a reliable standard of light have unanimously come to the conclusion that the sperm candle cannot in any way be regarded as an accurate standard. Nevertheless, the candle holds its own as the legal unit of light, owing largely to its convenience and the difficulty of providing another standard which shall be as handy to use and which will be more reliable under ordinary circumstances.

Attempts to secure greater uniformity of result from the standard candle

To obviate the inaccuracies of the sperm candle, many attempts have been made from time to time by the Gas Referees to ensure more uniform results. The candle was first of all to be lighted at least ten minutes before the test was made, at the expiration of which time the wick was to have a glowing tip at the end of a slight bend, as, when this condition is attained, the candle will be burning at its normal rate. Later on it was prescribed that all testings were to be rejected in which the consumption of the sperm was more than 126 or less than 114 grains per hour. In 1889 the relative positions of the candles and their wicks were clearly defined, and the observer was further directed to employ a fresh candle for each test; whilst in September, 1894, minute regulations for securing as far as possible uniformity in standard candles by attention to the material and treatment of the wicks and sperm, were added to the Gas Referees' instructions, and all the candles issued for official gas-testing in London are at present examined and certified for use by them.

In spite of all these precautions, however, the candle

still remains an unsatisfactory standard, and, in consequence, many other forms of standard have from time to time been suggested, amongst which may be mentioned Keate's lamp, introduced in 1869, which was practically a modified form of the "Moderator" lamp. This lamp, when burning sperm oil at the rate of 925 grains per hour with a 2-inch flame, yielded a light equal to 16 candles. This lamp was modified by Sugg, who added to it what was practically a Methven slot, and it then gave more constant results than had been obtained from candles, but its general performances were not good enough to warrant its adoption.

Keate's lamp

The Carcel

The French standard of light is the Carcel lamp, dating from 1800, which burns refined colza at the rate of 42 grammes per hour, the light given equalling 9·5 English candles.

The Hefner Alteneck unit

The standard due to Hefner Alteneck consists of a lamp burning the vapour of amyl acetate, the wick being contained in a round tube of German silver 8 mm. in diameter and 25 mm. high, and regulated so as to produce a flame 40 mm. high. This lamp ought to yield a light equal to one candle, but Dibdin found that the flame had to be increased in height in order to equal the light emitted by the Methven screen per candle. The red or yellowish-brown colour of the flame, which renders the task of comparing the light to be tested a difficult one, is the great drawback to this standard.

Violle Platinum standard

Another standard was suggested by Violle, but its impracticability rendered its use impossible, as he proposed to employ the light emitted by one square centimetre of platinum at the point of fusion.

The Methven Screen

The Methven screen, first introduced in 1878, is one of the more convenient forms of standard that has been proposed, and is largely used at the present day in gas-works. It consists of an upright metallic plate, fixed in front of a London argand. This plate has an opening which is covered by a slotted silver plate, the

opening of which is of such size that an amount of light equal to that afforded by two average standard sperm candles is allowed to pass through when the gas flame is three inches in height. It is only within certain limits that it is possible to get a constant light from a small portion of a gas flame, and although these limits are well within the illuminating value of the London gas supply, it is better to obtain greater constancy by using an aperture of smaller area and carburetting the gas with pentane.

The Harcourt pentane one candle unit

The standard proposed by Vernon Harcourt in 1887, and described at the British Association meeting in that year, was an entirely new departure. The burner consists of a brass tube 4 inches in length and 1 in diameter, the upper end being closed by a brass plug half an inch thick, in the centre of which is a round hole one quarter of an inch in diameter. A glass cylinder 6 inches by 2 inches surrounds the tube, the top of which is level with the top of the burner. At a height of 62·5 mm. above the burner is stretched a piece of platinum wire 2 to 3 inches long and about 0·6 mm. thick. The gas to be consumed in this burner is passed through a small meter, which registers one-sixth of a cubic foot at each revolution, and then through a governor which regulates the supply to half a cubic foot an hour. The height of the flame is so adjusted that it appears to touch the platinum wire, but not to pass it, the platinum being fixed directly above the flame and extending half an inch on either side of it.

Method of using the pentane unit

A special gas is used in this burner, and it is made by mixing in a gasholder air and liquid pentane in the proportion of 1 cubic foot of air and 3 cubic inches of pentane. The pentane is obtained from light petroleum, which is distilled at 60°, 55°, and twice at 50° C., and has to answer to the test of only faintly colouring one-twentieth its own bulk of fuming sulphuric

Pentane and its preparation

acid on agitation with it for five minutes. The density of the liquid must be between 0·62 and 0·63 at 62° F.; the liquid must volatilise at ordinary temperatures without leaving any residue when the tension of its vapour is not less than 7·5 inches of mercury. Its vapour density as compared with air must not be less than 2·47 or greater than 2·53.

Drawbacks to the standard

The chief drawbacks to this standard are that the personal equation of the observer affects this unit of light to a considerable extent, it being difficult for two observers to fix the flame at the same height, whilst the flame is also affected by vibrations and draughts.

Advisability of a higher standard

After all the endeavours to obtain a standard burner which shall emit a constant light of small intensity, the opinion is generally gaining ground that it is preferable to employ a standard light which shall nearly approximate to that yielded by the flame undergoing comparison. Dibdin devised, to meet this

The Dibdin ten-candle standard

requirement, a ten-candle pentane argand, which consumes gas carburetted with pentane, or a mixture of pentane vapour and air similar to that employed in the Harcourt unit. The argand burner is of special construction, giving a very full-bodied flame, the top of which is cut off by a screen, exposing a fixed height of flame. This burner, from the constancy of the results obtained by its use, its ease of manipulation, and the small extent to which it is affected by external causes, is the standard recommended by the Photometric Committee of 1891 to 1894; but its adoption in place of candles has not been effected, and in the testing of London coal gas the candle is now being replaced by a ten-candle pentane standard

Harcourt ten-candle pentane vapour standard

introduced by Harcourt, in which air saturated with pentane vapour descends by gravity to a steatite ring burner. The flame is drawn into definite form, and the top of it hidden from view by a long brass

chimney above the burner. This chimney is surrounded by a larger brass tube, through which hot air rises, and descending by another tube supplies air to the centre of the steatite ring. The upright carrying the burner has its tripod base fitted with levelling screws, and at the top bears a metal bracket on which is fixed the vessel containing the pentane, and from which the air, saturated with the vapour, descends by a rubber tube to the burner, the rate of flow being regulated by a stopcock. The lower end of the chimney should be 47 mm. above the top of the steatite burner, and is fitted with a small mica window, through which the height of the flame can be observed for regulation. The tip of the flame should be about half-way between the bottom of the mica window and the crossbar.

Drawbacks to the use of such mixtures as a standard unit

No matter how accurately standardised, or how uniform in action such standards may be, they are unfitted for anything but testing flames giving the same quality of light as they do themselves, whilst the fact that the so-called "pentane" is simply a distillate rich in that hydrocarbon renders the reproduction of the standard less certain than if a definite compound like acetylene were employed.

Violle Acetylene standard

Violle [1] made a standard burner in which acetylene, under a pressure of 0·3 m.—12 inches—escaped from a small conical jet into an atmospheric burner, and the mixture of acetylene and air was then consumed at a flat flame nozzle, and gave about 100 candles for a consumption of 58 litres (2·05 c. ft.). Only a portion of the flame was used, the remainder being screened off, and Violle found that the light differed but little from that emitted by his platinum standard unit.

Féry's Acetylene standard

Féry [2] also proposed using acetylene as a photometric standard. In order to do this, he burnt a jet of

[1] *Compt. Rend.*, 122, 79.
[2] *Compt. Rend.*, 126, 1,192.

acetylene at the end of a piece of capillary thermometer tube, the bore of which was 0·5 mm. in diameter, and experimentally determined the ratio between the light emitted and the height of the flame, which he gives in the following table :—

Ratio between the height of an Acetylene jet and the light emitted

Height of jet.		Consumption of gas per hour.		Intensity.		
				Observed.	Calculated.	Error.
millimetres.	inches.	litres.	cubic feet.			
5	·19	1·15	0·04	0·056	0·000	+0·056
10	·38	2·02	0·07	0·325	0·318	+0·007
15	·57	2·80	0·09	0·670	0·669	+0·001
20	·76	3·52	0·12	1·020	1·020	0·000
25	·95	4·28	0·15	1·380	1·372	+0·008
30	1·14	5·00	0·18	1·660	1·724	−0·064
35	1·33	6·00	0·21	1·910	2·076	−0·166

These figures he obtained by testing the jet of varying height against a jet of constant height taken as unity, and concludes that between the limits of 10 and 25 mm. the intensity is proportional to the height of the flame.

Advantages of Acetylene as an International unit of light

The author has found that such traces of air as are present in the gas when prepared with ordinary care do not affect the light emitted by the acetylene jet, and that by screening off the top and bottom portions of a jet burning from a standard nipple by far the best photometric standard obtainable can be produced. An international unit based on such a process would go far to remove the confusion created by such various standards as the candle, Carcel, Hefner lamp, and pentane units.

Acetylene as a standard for plate testing in photography

The characteristics of the light yielded by acetylene being so nearly akin to daylight, it would also prove a valuable standard for plate testing in photographic work, and also as a source of light in taking and printing photographs.

As has been pointed out, the smaller and more intense a source of light becomes, the harder and blacker will be the shadows thrown by it; and as the light of the electric arc is chiefly emitted by the small crater in the negative carbon, a considerable amount of light has to be wasted when using it for photographic purposes in securing sufficient diffusion to prevent harshness in the result.

Advantages of Acetylene over Electric Light for photographic purposes

This trouble is far less with acetylene, as the flame has a considerable area; and as the light necessary for a short exposure has to be obtained from several small flames, these can readily be so arranged and screened as to give most excellent results.

Value of Acetylene as compared with other sources of light for photographic work

The value of acetylene in photographic work is now universally recognised, and Walmsley has determined its relative value as compared with the ordinary sources of light by determining the time needed to fully expose carefully prepared plates, with the following results:—

	seconds.
Direct sunlight	1
Acetylene, 1 c. ft. burner	3
Diffused daylight, reflected from mirror	12
Incandescent mantle	24
Coal gas, Oil gas, Oil lamp	240

Vidal has, on the other hand, experimented with the acetylene light for photographic purposes, and has compared its value with that of a candle taken as unity.

Vidal's results

Candle	1
Coal gas	12
Welsbach mantle	44
Acetylene flame	150

It is manifest, however, that unless the exact conditions of the experiment are stated, but little is to be learnt from it save that acetylene is distinctly better than the Welsbach mantle for photographic work.

Practical conditions for the use of Acetylene

In practice it has been found that the best conditions for taking photographs by acetylene light is to have two stands, one carrying a cluster of 15 burners at a height of 6 or 7 feet from the ground. A reflector of glazed white paper stretched on a screen is placed behind this in such a way as to reflect the light towards the object to be photographed, whilst in order to properly diffuse the light a screen of thin transparent tissue paper is placed between the light and the object. A second cluster of 5 burners is arranged in the same way on the opposite side of the sitter, and excellent results are obtained with an exposure of 10 to 12 seconds.

More rapid results are obtainable by using clusters of burners with metallic reflectors, but the results are not so artistic owing to too great a concentration.

The cost would not be by any means prohibitive. The present price of carbide is £20 a ton; but supposing it to be retailed at £56, this would be 6*d.* per lb., which of good quality would yield in any decent generator enough gas to keep the 20 one cubic foot burners going for 15 minutes, and would mean about a halfpenny for each negative taken.

Acetylene for copying and printing

For copying and printing also acetylene should prove a boon. It is almost too brilliant and actinic for bromide paper, but ordinary gelatino-chloride paper can readily be printed by it. With an average negative of a yellow colour, an exposure of 1½ hours gives a fully printed result when placed at about 6 inches from the flame; but, of course, the time can be considerably shortened by slightly printing and then developing by any of the recognised methods.

Acetylene for projection work

Acetylene is also to a certain extent used for projection work; but it is not so well suited for this, as, in common with multiple wick oil lamps and incandescent mantles, the flame offers too large a surface of illumination.

Molteni's experiments on the value of various sources of light for projection

Molteni has attempted to determine the projection value of various illuminants by a photometric process in the following way. The measurements were made with an ordinary lantern, the stage of which carried an opaque card in which was cut an aperture 0·7 cm. square, and the distance of the lantern from the screen was such that each side of the square on the screen measured 1 metre.

Method of experiment

The screen was replaced by a disc of paper, the opposite side being illuminated by a standard lamp burning 42 grammes of oil per hour. The distance of this lamp was varied in order that equality of illumination might be obtained on the screen, and the photometric values of the light were determined by the distance of this lamp.

Results

Multiple wick lamp	1·00
Incandescent gas, No. 2 burner, no reflector	1·00
Acetylene 1 burner, no reflector	1·00
„ 2 „ „	1·70
„ 3 „ „	3·20
„ 4 „ „	4·10
„ 5 „ „	4·50
Limelight, alcohol and oxygen	5·80
„ oxyhydrogen	16·60
„ etho-oxygen	18·50
Electric incandescent, 32 candle power	0·68
„ „ 50 „ „ vertical	0·93
„ „ 50 „ „ horizontal	0·93
Electric focus, 100 candle-power	3·82
„ arc lamp, 7 ampères	39·03
„ „ 10 „	75·61
„ „ 12 „	86·50
„ „ 15 „	117·61
„ „ 20 „	160·80

The sanitary position of Acetylene as an illuminant

The researches of Dr. Grehant have shown us that, when burning with a smokeless flame, no carbon monoxide can be detected in the products emitted by the combustion of acetylene, and its sanitary position will therefore be defined by the amount of oxygen ab-

stracted from the air and carbon dioxide produced as compared with other illuminants.

Taking the average-sized room, which would be well lighted by an illumination equal to 64 standard candles, we find that this amount of light from various illuminants would have the following effect on the atmosphere :—

The effect of various illuminants on the air of a dwelling-room

Illuminant.	Oxygen removed from air. c. ft.	Products of combustion. Water vapour. c. ft.	Products of combustion. Carbon dioxide. c. ft.
Sperm candles . . .	38·5	26·2	43·6
Paraffin oil	24·9	14·0	39·8
London gas—Batswing .	26·1	29·4	19·2
,, Argand . .	23·0	25·6	17·0
,, Regenerative.	10·6	8·3	5·2
,, Incandescent.	3·1	4·6	1·8
Acetylene	5·0	2·0	4·0

So that light for light it fouls the air less than any of our ordinary illuminants, with the exception of the incandescent gas-burner.

Heating effect of the Acetylene flame

In comparing the heating effect of various illuminants on the air of a room, it is necessary to determine the calorific value of the combustion of a cubic foot of the illuminating gas employed ; and it is manifest from theoretical considerations that a highly endothermic compound like acetylene must have a far higher heating power than ordinary coal gas. The mean of a number of experiments made in Juncker's calorimeter gave as the thermal value of the ordinary London coal gas supply 158 calories, whilst under the same conditions acetylene yielded 320.

The theoretical amount of heat emitted by the combustion of a cubic foot of acetylene is 349·08 calories, but this would only be given by the absolutely pure and dried gas, and the experimental number deter-

mined in the calorimeter represents more truly the heating power of the moist gas under ordinary existing conditions.

Heating effect of various illuminants on the air of a room

Taking now the case in which a room is lit up with a power equal to 64 candles, we find that if we call the heating effect produced by an incandescent mantle giving this amount of illumination 100, then—

RATIO OF HEAT EMITTED TO YIELD A LIGHT OF 64 CANDLES.

Incandescent mantle	100
Acetylene	115
London Argands	571
Flat flame burners	914

so that for all practical purposes the heating effect on the air by acetylene illumination is the same as with mantles.

Comparison of the cost of Acetylene and coal gas lighting

When one comes to compare the cost of acetylene and coal gas, one is struck by the boldness of the statements made by its advocates as a rival to the well-established coal gas industry. At the present time the wholesale price of carbide is £20 a ton, but I believe that to fill large cash orders it can be obtained at £16 at Foyers, which would mean at least £20 a ton at the works where it is to be decomposed and the gas distributed. The decomposition of carbide is not a costly operation, but at least 10 per cent. would have to be added to the price of the carbide for handling, water, repairs, interest on plant, purification, etc., and this would bring the price of the acetylene to £2 per 1,000 in the holder. Coal gas, when made on the scale common in our big cities, costs, however, about 1*s*. 2*d*. per 1,000 in the holder, and about 100 per cent. has to added to this to cover charges of distribution and profit. The power of doing this is dependent on the amount of gas sold, and whilst the South Metropolitan can make a fair profit on gas at 2*s*. 3*d*. per

Causes governing the price of gas

1,000, there are many small country works that cannot pay a dividend with gas at three times the price. With acetylene the smallness of the output would necessitate a heavy charge over cost price, and an installation of acetylene even in a fair-sized town would not be likely to pay its way with a less charge than £3 per 1,000.

Looked at from this point of view, it is at once manifest how absurd it is to talk of acetylene as a possible rival of coal gas, and the sooner this is realised the better will it be for the future of this brilliant illuminant.

Abroad, where coal gas is dear, it is possible, by taking the price of acetylene in the holder, and comparing it with distributed coal gas, to make acetylene out to be light for light as cheap as the latter when consumed in a flat flame burner; but even this method of calculation breaks down before the high light emissivity of the incandescent mantle.

The true field for Acetylene lighting

It is in those districts where no coal gas exists that the true field for acetylene is to be found, and here its ease of generation and the beauty of its light makes it a pleasant companion after the greasy dimness of the candle, or the smell of the oil lamp.

In view of the exaggerated statements made by company promoters and other interested persons, the author has felt so strongly the necessity of great care in stating the facts of the case as regards the relative value of acetylene as compared with other illuminants, that he has been several times accused of doing the new illuminant injustice.

The value of the hygienic side of the question

There is no doubt that the small amount of pollution to air due to the combustion of purified acetylene, and the comparatively small amount of heat given off per unit of light emitted, make acetylene a most valuable illuminant; and an article appeared in the *Engineer* of March 31st, 1899, which is so able, and

states the case for acetylene so clearly and fairly, that the author felt constrained to reproduce portions of it.

The basis of comparison between Acetylene and other illuminants

Speaking of the real value of acetylene as an illuminant, the writer says: "The hydrocarbon is capable (*a*) of manufacture in a central factory to supply a village or small town where local conditions would cause coal gas to be too expensive, or (*b*) of generation in isolated country houses, etc., for their own illumination. It therefore becomes a possible competitor with (*a*) inferior — say 14 candle — coal gas, (*b*) more frequently with paraffin oil; and the trial between them will be conducted on two issues: (*a*) the relative expense, (*b*) the relative hygienic value.

The price of Acetylene

To make the necessary comparisons certain data must be fixed. These are as follows: Calcium carbide costs £20 per ton, yields 5 c. ft. of acetylene per lb., the value of which for material alone is £1 15*s.* 9*d.* per 1,000 c. ft. Take case A, where water, labour, interest, depreciation, etc., have to be paid for. The holder price of the gas, as agreed by Lewes, Fowler, and other authorities, is £2 per 1,000. If it were to be distributed and sold at a reasonable profit, the charge should be approximately £4 per 1,000. In case B, as will be argued later, with a medium-sized middle-class house, burning between 10,000 and 12,000 ft. per annum, the cost to the occupier should be nearly £2 3*s.* per 1,000. Coal gas is burnt in one of two ways, in the old flat flame burner or with the mantle. The former yields about 2 candles per foot when the gas is of 16 candle power; but in such country places where it might possibly be attacked by acetylene, it would certainly not be enriched, and would therefore be of 14 candle power; but this small difference may be overlooked. With the mantle it gives 17 candles per foot. The illuminating power of ordinary petroleum

has been recorded by many observers, and the figures differ widely; as a fair average it may be taken that one gallon of oil yields 1,400 candle hours in a large duplex lamp, 700 candle hours in a small one. The price is known to everybody. The highest duty that can safely be ascribed to acetylene for any length of time is 32 candles per ft. in a 1-ft. burner. Collating these results Table I. is arrived at, which represents the quantities of coal gas and petroleum which are equivalent as illuminants, and the prices at which they would have to be sold to render them pecuniarily equal to acetylene made from carbide at £20 a ton.

Comparison of the cost of Acetylene with coal gas and oil lamps

TABLE I.—COMPARATIVE PECUNIARY VALUE OF DIFFERENT ILLUMINANTS.

Acetylene.			Coal Gas.			Paraffin.		
Carbide per ton.	Price per 1,000 c. ft.	Unit taken c. ft.	How burnt.	Equivalent number of c. ft.	Equivalent price per 1,000.	Kind of lamp.	Equivalent number of gallons.	Equivalent price per gallon.
£. 20	80*s.*	1,000	luminous	16,000	5*s.*	small	46	1*s.* 9*d.*
			mantle	1,880	42*s.* 6*d.*	large	23	3*s.* 6*d.*
20	43*s.*	1,000	luminous	16,000	2*s.* 8*d.*	small	46	11*d.*
			mantle	1,880	22*s.* 10*d.*	large	23	1*s.* 10*d.*
15	60*s.*	1,000	luminous	16,000	3*s.* 9*d.*	small	46	1*s.* 4*d.*
			mantle	1,880	31*s.* 10*d.*	large	23	2*s.* 7*d.*
15	34*s.*	1,000	luminous	16,000	2*s.* 1*d.*	small	46	9*d.*
			mantle	1,880	18*s.* 1*d.*	large	23	1*s.* 6*d.*

Cost of Carbide

In his recent course of Cantor lectures, Lewes has stated the total manufacturing cost of calcium carbide as being £7 to £8 per ton, which points to a possible future selling price of about £15 per ton. In order to see how matters would stand if ever this reduction should take place, the table also includes the values of acetylene from £15 carbide; but it must be distinctly remembered that all these figures in Table I.

refer simply to relative costs, and have nothing whatever to do with the hygienic value of acetylene.

Impossibility of Acetylene competing with coal gas as consumed in the incandescent mantle

Now it is perfectly clear from an examination of these results that if people make use of the Welsbach mantle, acetylene cannot under any circumstances at present—it may almost be added, or in the future —compete with coal gas as an economical illuminating agent, for the difference of two or three candles per 5 c. ft. between London and country gas when burnt in a luminous flame does not affect the efficiency of the incandescent light. If, on the contrary, people persist in retaining their batswings and fishtails, home-made acetylene will be cheaper than coal gas in many country places, and even if it be supplied by a company will be equal to the price charged for the latter in most villages. At present prices, acetylene in either form is far more costly than paraffin if the oil be burnt in good duplex or argand lamps; but in the small lamps employed in less important situations the two illuminants are almost equal in price, assuming that the gas is made on the premises.

Conditions for maximum efficiency

All gaseous and liquid illuminants are alike in one respect—to obtain the maximum efficiency from them they must be consumed in the largest burners possible. The incandescent gas light cannot be turned down, and there is no practical method of producing a small flame just powerful enough for halls and lobbies. Paraffin, coal gas, and acetylene can be consumed in as small burners as may be desired, but at a vastly increased cost per unit of light. Now, to illuminate a house properly, a certain number of flames are required as well as a definite amount of candle power per hour. If all the light were to be employed in one apartment, x candle hours of paraffin, of gas, and of acetylene would be all equally useful, and therefore the comparison is properly made—as is done in Table I.

Difficulties in the way of making a fair comparison

—by calculating the cost of each x. But it does not follow that each x can be divided into a dozen or so different portions without affecting the accuracy of the calculation. Thus, 27 cubic feet of acetylene could be burnt per hour in 27 1-ft. burners, yielding 918 candles, or in one hundred 0·27-ft. burners, yielding only 320 candles; and a similar state of affairs exists with coal gas and paraffin. A difficulty at once crops up in considering the cost of acetylene as a substitute for oil or unenriched coal gas; as for obvious reasons the same number of flames should be retained, and the same quantity of light produced; yet if both points be attended to simultaneously, acetylene is treated very unfairly, because much of it must be burnt under the worst conditions as regards economy. If the number of flames be kept constant—as must evidently be done in practice—and each flame be the best of its kind, acetylene lights the whole house more brilliantly than oil, and the paraffin is treated unjustly by being represented as an inferior illuminant. In fact, it is scarcely feasible to keep both factors unaltered with a due regard to efficiency; and as the degree of light is less important than the illumination of each particular room and passage, an allowance must be made when contrasting the increased cost of acetylene for the greater brilliancy of the several apartments and the whole abode.

Factors that must be taken into considera-tion

In order to ascertain with somewhat greater accuracy the exact monetary effect of supplanting an installation of petroleum lamps by an acetylene generator located in an outhouse, the state of affairs existing in a typical middle-class country residence may be examined. In such a house the bedrooms are lighted by candles, and would remain so; lamps are used on the ground-floors, *i.e.* the sitting-rooms, halls, passages, kitchen, and "usual offices." With a population of six or eight, ten lamps are required

The conditions existing in an ordinary country house

nightly; the household retires about 11 p.m., and needs 1,800 × 10 burner hours per year—the hours between dusk and 11 p.m. are 1,821 per annum. Half the lamps, say, are large, yielding, as before mentioned, 1,400 candle hours per gallon; the other half are small, burning half as much oil per hour, and yielding 700 candle hours per gallon. "The mean output of light is accordingly 1,167 candle hours per gallon. The average annual consumption of oil in such a house is 184·5 gallons. The number of candles produced per year is, therefore, 184·5 × 1,167 = 215,250, or 119·6 per hour. To obtain the same amount of light, neglecting the number of flames, would require $\frac{215{,}250}{32 \times 5} = 1{,}345$ lbs. of calcium carbide, and would cost £12; the corresponding expense for the petroleum at 8*d.* would be £6 5*s.*; at 10*d.*, £7 14*s.* To deal with the ten flames themselves requires a digression. Acetylene can be burnt in various-sized jets of the Naphey type, the duty for three of which may be quoted (Lewes):—

Light given by oil lamps per gallon of oil

TABLE II.—ILLUMINATING POWER OF ACETYLENE.

Number of burner.	Gas consumed. c. ft.	Light in candles.	Candles per c. ft
15	0·40	8·0	20·0
25	0·65	17·0	26·6
40	1·00	34·0	34·0

The last of these is elsewhere given by Lewes as only yielding 32 candles per foot, and the lower value is adopted throughout this article. In the dwelling rooms of course the largest burners will be used, but in the hall, etc., a light of 8 candles would be sufficient. It is next to impossible so to arrange these jets that the ten shall together emit 120 candles per hour. Two of No. 40 and eight of No. 15 would yield 128 candles, but perhaps the best method is either—scheme 1—two of No. 40, two of No. 25, and 6 of No. 15 = 5·7 c. ft., and 146 candles per hour altogether, or,

The loss of light in using small Acetylene burners

as half the paraffin lamps are large and half small—scheme 2—five of No. 40, and five of No. 15 = 7·0 ft. and 200 candles per hour.

Capital expenditure in the rival installations

The capital outlay on the petroleum installation will be 12 lamps—two or three in reserve are always wanted—say £5; storage vessel, fillers, etc., £2; total £7. The capital expenditure on acetylene will be: generator with purifier affixed, say £15; piping ground floor of house with connection to shed, £10; ten gas brackets, £5; total £30. Scheme 1 would require per year 10,260 c. ft. of acetylene = 2,052 lbs. carbide = £18 7*s.*; Scheme 2, 12,600 c. ft. of gas = 2,520 lbs. of carbide = £22 10*s.* at £20 a ton. If calcium carbide should fall to £15, scheme 1 would cost £13 15*s.* 3*d.*; scheme 2, £16 17*s.* 6*d.*, for material alone. The annual expenditure with paraffin is thus:—

Comparison of cost of oil and Acetylene installation

	8*d.* per gallon. £ *s.* *d.*	10*d.* per gallon. £ *s.* *d.*
184·5 gallons	6 4 8	7 13 9
10 per cent. depreciation on £7	0 14 0	0 14 0
5 per cent. interest on £7	0 7 0	0 7 0
Wicks and chimneys	0 5 0	0 5 0
	£7 10 8	£8 19 9
Candles per hour	120	120

The annual expenditure with acetylene is:—

	£20 carbide. Scheme 1. £ *s.* *d.*	£20 carbide. Scheme 2. £ *s.* *d.*
Calcium carbide	18 7 0	22 10 0
10 per cent. depreciation on £15	1 10 0	1 10 0
5 per cent. interest on £30	1 10 0	1 10 0
Purifying material, say	0 5 0	0 5 0
10 new burners	0 10 0	0 10 0
	£22 2 0	£26 5 0
Candles per hour	146	200
Cost per 1,000 c. ft.	43*s.* 1*d.*	41*s.* 9*d.*
Pounds of carbide decomposed per 24 hours, mean	5·6	7·0
maximum	7·5	10·0

Were the carbide procurable at £15 per ton, scheme 1 would cost £17 10*s.* 3*d.*, or 34*s.* 2*d.* per 1,000 c. ft.; scheme 2, £20 2*s.* 6*d.*, or 33*s.* 9*d.* per 1,000. Labour and carriage have been omitted on both sides, and should approximately balance one another. The trouble of cleaning lamps would be greater than charging a generator, the carriage of carbide from the nearest station heavier than that of the petroleum casks. Water has not been charged, for the countryman does not have to ask counsel's opinion as to what is a "domestic use" each time he handles his pump. **Comparative labour**

Thus far the three illuminants have been compared with one another simply on the lines of their relative efficiency and expense. But there are other matters which go to make up the suitability of any substance or operation for employment in a dwelling-house—simplicity, elegance, and hygienic qualities. It is usually assumed by manufacturers and others, that the average member of the public will estimate the value of any new claimant for his favour chiefly on a monetary basis, and the said manufacturer drafts his advertisements and arguments to meet this supposed position. We may take leave to doubt the accuracy of this notion. The ordinary male householder certainly places simplicity first; his wife perhaps ranks decorativeness before everything else. Seeing that the "average man" is a purely mathematical abstraction, and is never met with in real life, it is difficult to prophesy what he would do should he ever appear in the flesh; but there is absolutely no question of what he ought to do and would do if he were properly instructed. By far the most important criterion for judging the domestic value of any new process is the effect it shall have on the health of its employers; simplicity, elegance, and cost are all relatively quite insignificant, and their position one against the other may be determined by each indi- **Importance of hygienic considerations over all others**

vidual for himself. As regards trouble, the luminous gas flame is manifestly the best, acetylene, incandescent gas, and paraffin are all roughly equal; in elegance, the gas mantle is probably worst, the others about equal. Expense has already been dealt with.

The effect of flames of hydrocarbons on the air

The proper method of comparing acetylene with its rivals is to ascertain the effect each light produces on the atmosphere of a room, to see which illuminant approaches nearest to the ideally perfect electric light in its absolute harmlessness to health. Combustion of a carbonaceous material without a flue leads to four separate results on the surrounding air: abstraction of oxygen, evolution of moisture, of carbonic acid and production of heat. Each of these is unpleasant and more or less objectionable, and either may be made the basis for comparison. Table III. records the relative effect on the atmosphere of an unventilated apartment during the production of a uniform quantity of light for the same period of time, taking acetylene as the unit in all cases. The figures are recalculated from data given by Lewes, with the exception of the heat of petroleum. This being unmentioned by the Cantor lecturer has been deduced from a series of papers in the *Journal für Gasbeleuchtung*, vol. xxxiv., by E. Cramer, who gave the heat production of paraffin in comparison with the argand gas burner; and as Lewes has quoted the relationship between the argand and the acetylene, it is merely a matter of arithmetic, assuming the two varieties of coal gas to be fairly similar in composition, to interpolate the oil figures. Unfortunately, Lewes has not stated what kind of lamp his results were obtained from; whereas Cramer represents the duplex or large circular paraffin burner to be three times as powerful as the small. Other observers have generally made the relative efficiency about 2 to 1, as indicated in the first part of this article, and perhaps Cramer has rather exagger-

Data for the comparison of the effect of Acetylene and oil lamps on the air

ated the difference, or employed abnormally bad small lamps.

Table III.—Comparative Hygienic Effect of Illuminants per Unit of Light.

	Carbonic acid evolved.	Moisture evolved.	Oxygen removed.	Heat produced.
Acetylene	100	100	100	100
Gas, flat flame	480	1,470	520	795
Gas, mantle	45	230	62	87
Petroleum, small lamp / " large lamp	995	700	498	738 / 246

Results

It has already been pointed out that there may be some difficulty in replacing an existing installation of gas or oil lamps in a country house without increasing the total luminous effect, unless the occupier is content to burn much of the acetylene most wastefully. Recalculating Table III. to suit the second scheme previously suggested, Table IV. is arrived at,

Table IV.—General Effect of Various Illuminants per Flame.

Material used.	Cost per unit.	Number of flames.	Candles per hour.	Cost per annum.	Carbonic acid evolved.	Heat produced.
	s. d.			£ *s. d.*		
Acetylene, home-made	43 0	10	200	26 5 0	100	100
Acetylene, home-made	34 0	10	200	20 2 6	100	100
Acetylene, supplied	80 0	10	200	50 8 0*	100	100
Acetylene, supplied	60 0	10	200	37 16 0*	100	100
Petroleum	0 8	10	120	7 10 8	597	295†
Petroleum	0 10	10	120	8 19 9	597	295
Gas, flat flame	x	10	120	5 4 0x*	288	477
Incandescent	x	10	150	3 7 5x*	34	65

* For material only. † Mean of Cramer's figures.

which shows the general result of adopting a system of ten acetylene lights, giving 200 candles in place of ten oil lamps, emitting 120 candles per hour, while ten luminous gas flames—which would not be sufficient—burning 6 c. ft. per hour, at 2 candles a foot, and ten incandescent burners at $\frac{3}{4}$ ft. and 15 candles per hour, are also included, x in the latter case being the price in shillings charged per 1,000 ft. for the coal gas supplied.

Comparison with coal gas flames

Therefore the employment of a scheme of acetylene lighting best suited to the requirements of the typical country house taken for illustration throughout this article, in place of a battery of five large and five small paraffin lamps, carbide at £20 a ton, petroleum at 8*d.* or 10*d.* per gallon, would lead to the following results :—

Balance of loss and gain

Increase in light	67 per cent.
Increase in cost	192–242 ,,
Decrease in carbonic acid	83 ,,
Decrease in heat	66 ,,

If now to arrive at the hygienic effect of an illuminant the output of carbonic acid is averaged with that of heat, and if for the moment the absurd proposition be accepted that money is of equal importance with health, acetylene, which reduces the former to one-sixth and the latter to one-third—mean $\frac{1}{4}$—of their present proportions, increasing the luminosity by two-thirds, is shown plainly enough to be worth $4 \times \frac{3}{2} =$ six times as much as paraffin; whereas, at the present market price, it only costs three or three and a half times as much. But when it is remembered that efficient ventilation is almost impossible in ordinary houses; that much discomfort is caused by dwelling in rooms with too little oxygen, too much carbonic acid, the upper layers of air hot and "stuffy"; that constant respiration of vitiated air makes for imperfect oxygenation of the blood, headache, dys-

Conclusions

pepsia, and permanent injury to the human system—in a word, that the value of good health is far above rubies, the absurdity of this method of comparison is obvious to all; and it is manifest that for domestic illumination acetylene is superior—infinitely superior, it might be said—to everything except the incandescent electric light and the Welsbach gas mantle. From this standpoint the comparative values of acetylene, coal gas, and paraffin are independent of any fluctuations in the price of the several raw materials, standing only to be revised if ever new methods of burning either illuminant shall vary the amount of deleterious carbonic acid and other noxious products emitted per unit of light. And from this sanitary standpoint, primarily, if not alone, should acetylene be judged by all householders who have at heart the health and well-being of themselves and their families."

Superiority of Acetylene from the hygienic standpoint

Carbide will probably some day become an important factor in the transmission of power, as a cubic foot of solid carbide would weigh 62·26 kilos or 137 lbs., and if of commercial purity would yield 685 c. ft. of acetylene, and have a thermal value of nearly 232,215 calories.

Carbide as a transmittor of power

In practice, however, the weight of carbide which can be got into a cubic foot space is dependent on the size to which the material is broken, and with the ordinary commercial carbide a fair average would be 80 lbs. per cubic foot, yielding 400 cubic feet of acetylene gas, with a thermal value of 139,600 calories. It is at once manifest that solid carbide is as economical a method of transporting acetylene as if liquid acetylene were employed, as the liquid will only yield about 400 times its own volume of gas, and the carbide has the advantage of being practically safe in transit.

The storage value of Calcium Carbide

There are several investigators at present working on the utilisation of acetylene for gas motors, but

Troubles to be overcome in the use of Acetylene as a motive power

there are many difficulties to be overcome before this is successfully accomplished, as the deposition of carbon when the air supply is insufficient, and the violence of the explosion, are troublesome factors to deal with.

Most of the experiments made on the use of acetylene for power have been of an unsatisfactory character, either from the gas engine employed not being suited to the gas, or from the recorded data being insufficient to base any definite conclusions on.

The pressure and explosive efficiency of mixtures of acetylene with air have been determined by Grover.[1]

Grover's experiments

The experiments were carried out in the following way: "A known volume of acetylene gas was admitted to a cylinder, and time allowed for its diffusion with the air therein. The mixture was ignited by electricity, and the pressure developed was measured by means of a Crosby indicator, the pencil of which worked upon a drum revolving at a known speed. In this way the proportions of acetylene and air, the time taken to complete the inflammation, and the pressures developed were observed. The products of combustion were analysed and the original mixtures checked. When any discrepancy was found, the quality of the original mixture was determined from the analysis of its products.

For compressing the mixtures before ignition a Westinghouse air pump was used.

Explosion at atmospheric pressures

The first series of experiments consisted in exploding mixtures of acetylene and air at atmospheric pressure. The temperature before ignition was observed after the gases had diffused for ten minutes. Mixtures ranging from 18 volumes of air to 1 of gas, and 4 of air to 1 of gas, were exploded. No weaker mixture than 18 to 1 could be fired at atmospheric pressure.

[1] Pamphlet published by Jowett & Sowry, Leeds, 1898.

The superior limit was not obtained by experiment, but it is known that mixtures of 1½ of air to 1 of gas will explode at atmospheric pressure, and that by heating pure acetylene when compressed to two atmospheres it explodes without air. The pressures obtained are given in Table I. With weak mixtures

Tables of the efficiency obtained

TABLE No. I.—MIXTURES OF ACETYLENE AND AIR EXPLODED AT ATMOSPHERIC PRESSURES.

Initial temperature, 32° F.

Proportion of air to gas.	Maximum pressure lbs. per sq. in.	Efficiency per cent.
18 to 1	54	47
15 to 1	74	53
14 to 1	83	56
13 to 1	83	53
12 to 1	89	54
11 to 1	95	58
10 to 1	103	64
9 to 1	108	68
8 to 1	111	71
7 to 1	112	73
6 to 1	106	71
5 to 1	102	70
4 to 1	101	71

Pressure as compared with mixtures of coal gas and air

of acetylene and air, the pressure was more than three times as great as with the same mixtures of coal gas and air. But with stronger mixtures of acetylene the increase of pressure was less than twice as great. In making such comparisons of the two gases, it must be remembered that coal gas requires 5·7 volumes of air to 1 of gas, whereas acetylene requires 12·5 volumes of air to convey the necessary oxygen for its complete combustion." This fact causes a wide difference if the results be contrasted by curves.

Rapidity of explosion with mix-

"Not less remarkable than the increase of pressure is the reduction of time for the complete inflammation

tures of Acetylene and air

of the gases. Thus it was found that inflammation was complete with acetylene mixtures in from 0·1 to 0·18 of a second, whereas with coal gas the times observed for the same mixtures were 0·5 to 0·25 of a second. 15 to 1 is the weakest mixture of coal gas that can be exploded at atmospheric pressure, but with acetylene the limit is 18 to 1. The maximum pressure recorded was with a mixture of 7 to 1. Subsequent experiments with the mixtures at more than 1 atmosphere showed that the true mixture to give a maximum pressure is nearer 11 to 1. Subsequent experiments with the mixtures fired at more than one atmosphere gave discordant results, and led the author to suspect that the true proportions of air and gas were not always identical with the proportions as measured by the apparatus. In the last series of experiments, where the discrepancies were most marked, the products of each combustion were analysed, and it was found that the true mixtures calculated from the products of combustion were weaker than the supposed mixtures. It was at first thought that the escape of the gases from the cylinder during the time allowed for their diffusion at the higher initial pressures was the cause of this discrepancy. That this was not the sole cause was shown by an analysis of the gas from the holder after it had been drawn from the acetylene generator. The acetylene, which was supposed to be pure, was found to contain from 6 to 20 per cent. of incombustible gas —chiefly air. The greater proportion of air was found in the generator immediately after charging it, but as the gas was drawn off the proportion of air gradually diminished. In no instance is it likely that pure acetylene gas is delivered from a small generator because of the inevitable secretion of air, and the diffusion of the gas with it during its expulsion. This is not detrimental when the generator is used for

Discrepancies in the experimental results and their explanation

lighting purposes, but care should be exercised in order to avoid ignition of an explosive mixture just after charging. The errors possible in the mixtures in the explosion cylinder, due to the air in the generator, may be estimated as follows:—

Admixture of air with the gas during generation

Let x equal supposed volume of air in the explosion cylinder when the volume of gas is supposed to equal 1. Then the supposed ratio of air to gas is represented by $x/1$.

Let $1/y$ equal actual volume of air in gasholder per 1 volume of gas and air.

Estimation of errors due to impure Acetylene

Then the true ratio of air to gas in the explosion cylinder equals $\frac{x+1/y}{1+1/y}$ which reduces to $\frac{xy+1}{y-1}$ equals $\frac{\text{true volume of air}}{\text{true volume of gas}}$. Now when $1/y = 1/5 = 20$ per cent. of air in generator, true volume of gas to air in explosion cylinder becomes $1{\cdot}25x + 0{\cdot}25$.

So $1/y = 1/10 = 10$ per cent. becomes $1{\cdot}1x + 0{\cdot}1$
$1/y = 1/20 = 5$ „ „ $1{\cdot}05x + 0{\cdot}05$
$1/y = 1/40 = 2\frac{1}{2}$ „ „ $1{\cdot}025x + 0{\cdot}03$

Experiments at two atmospheres pressure

The second series of experiments was made with the mixtures compressed to 15 lbs. per square inch above atmospheric pressure before ignition took place. In each of these experiments the weights of gas used were twice as great as in the first series. The gas required for each combustion was first measured at atmospheric pressure, and then driven over into the cylinder. All cocks were then closed, and compressed air was passed into the cylinder until the pressure gauge showed 15 lbs. The mixture was then stirred, and allowed to stand for ten minutes before ignition was attempted. It was found impossible to keep the pressure at exactly 15 lbs. owing to slight leakages past the valves in connection with the apparatus, but in all cases the pressure and temperature just before ignition were recorded and allowed for in making the reductions.

Methods of experiment

As the ratio of the gas increased, its leakage preponderated over that of the air, because the undiffused gas in the cylinder occupied the region near the indicator cock, as well as that near the inlet cock. The loss of pressure was never more than 2 lbs., and cannot seriously prejudice the results. The maximum pres-

Pressure results

TABLE No. II.—MIXTURES OF ACETYLENE AND AIR EXPLODED AT TWO ATMOSPHERES.

Initial temperature, 32° F.

Air to Gas.	Maximum pressure.
21 to 1	121
20 to 1	127
19 to 1	115
18 to 1	138
17 to 1	129
16 to 1	143
15 to 1	171
14 to 1	159
13 to 1	170
12 to 1	168
11 to 1	177
10 to 1	166
9 to 1	196
8 to 1	179

Results obtained

sure recorded was with a 9 to 1 mixture, and the time of inflammation was 0·02 of a second. The weakest mixture that could be fired was 21 to 1 as measured by the gasholder, and without corrections for air in the generator. Supposing there to be 10 per cent. of air in the gasholder, the true mixture would have been 23·1 to 1. It is not likely that there was so much air in the gasholder.

Four mixtures of coal gas in the proportions of 8 to 1 and 11 to 1 were fired at the same initial pressure; the maximum pressure of the acetylene explosions was found to be from 1·5 to 2·7, as great as with the corresponding mixtures of coal gas.

In the third series of experiments the mixtures were fired at 30 lbs. per square inch above atmospheric pressure. The strongest mixture fired was 11·7 to 1 and the weakest 30 to 1. It is probable that higher pressures would have been recorded with stronger mixtures, but it was inadvisable to experiment further in this direction, as the margin of safety of the explosion cylinder was nearing a safe limit. Moreover, it will ultimately be shown that the most economical mixture to use is not in the neighbourhood of 12 to 1, but very much weaker.

Experiments at three atmospheres pressure

TABLE No. III.—MIXTURES OF ACETYLENE AND AIR EXPLODED AT THREE ATMOSPHERES.

Initial temperature, 32° F.

Efficiency at three atmospheres initial pressure

Air to Gas.	Maximum pressure.	Efficiency per cent.
30 to 1	146	48
22 to 1	197	62
21 to 1	207	64
19·6 to 1	211	61
17·5 to 1	246	64
16·9 to 1	236	63
16·1 to 1	259	62
14·7 to 1	261	58
12·3 to 1	308	57
12·1 to 1	307	57
11·7 to 1	325	57

Troubles to be contended with

In this series the trouble due to leakage was accentuated, and sometimes the pressure dropped 3 to 4 lbs. per square inch during the time the gases were standing for diffusion. Having regard, however, to the fact that in all cases the products of combustion were analysed, and the results plotted according to the presence of air indicated by the analysis, it is probable that a higher degree of accuracy was secured in these experiments than in the former.

Analysis of products of combustion of mixtures of acetylene and air at three atmospheres.

Analyses of the products of combustion

Mixtures.	Constituents by volume per cent.					Totals.
Air—Acetylene.	Carbon dioxide.	Carbon monoxide.	Oxygen.	Nitrogen.	Steam.	
11·7 to 1	13·0	3·2	0·0	79·0	6·5	101·7
12·3 to 1	15·1	0·0	0·0	78·0	8·2	101·3
14·5 to 1	12·4	0·0	2·5	78·9	6·2	100·0
16 to 1	11·8	0·0	4·2	79·0	5·9	100·9
17·5 to 1	10·0	0·0	5·1	79·6	5·0	99·7
21 to 1	8·6	0·0	8·1	78·9	4·3	99·9
22 to 1	9·0	0·0	8·6	79·0	4·5	101·1
30 to 1	6·8	0·0	12·0	78·5	3·4	100·7

Results

352 lbs. per square inch was the highest pressure recorded with an 11·7 to 1 mixture fired at three atmospheres. The lower limit, namely 30 to 1, gave a pressure of 180 lbs. per square inch. To produce such a pressure with coal gas a mixture of 9 to 1 was needed.

Time taken during explosion

The time to attain to complete inflammation of the gases was found to be from $\frac{13}{1000}$ for strong mixtures to $\frac{2}{10}$ of a second for the weakest mixture. It must be noted here that the times recorded by the indicator include a considerable error due to the inertia of the piston and other moving parts of the indicator; and, further, that the shorter the time recorded, the greater will be the error due to these causes.

Calculation of the temperatures produced

From the diagrams obtained during the explosion of the mixtures the temperatures of the products of combustion can be calculated, on the assumption that the laws of Mariotte and Gay-Lussac are true for these high temperatures and pressures. M. Berthelot, writing on this subject, says, "The laws of Mariotte and Gay-Lussac are hardly applicable in the case of enormous pressures such as those observed in the combustion of powder. With greatly compressed gases the pressure

varies with the temperature much more rapidly than would follow from these laws: it approaches the rate observed by physicists in the study of vapours. For a given temperature the pressure is therefore generally higher than that which would be given by calculating according to the ordinary laws of gases. This tends to compensate in the calculation of pressures the contrary influences exercised by the variation in the specific heats.

Method of calculation employed

The theoretical temperature, on the assumption that no heat is transferred to the walls of the cylinder during inflammation of the gases, can be calculated in the following way: The calorific value of acetylene is 1,504 B.T.U.'s per cubic foot at 32° F. when the water formed by its combustion is not condensed. The weight of the mixtures and the true volumes of air and acetylene are determined from the products of combustion. It remains, then, to find the specific heat of the products. There is some difficulty in this because of the inaccurate knowledge of the specific heats of gases at high temperatures. Thus the specific heat of steam at 3,600° F.—a temperature reached in the experiments—has been given by Mallard and Le Chatelier as 0·68, that of carbonic acid as 0·308, and nitrogen 0·205. The specific heat of oxygen and carbonic acid are nearly the same at low temperatures, and it has here been further assumed that the specific heat of oxygen at high temperatures is the same as carbonic acid. Even if this assumption be incorrect, the error in the specific heat of the mixtures experimented on is insignificant, because the proportion of oxygen present in the products is very small in comparison to the nitrogen—the chief constituent in determining the specific heat.

The phenomena of dissociation have an important bearing on the question of efficiency as calculated from these experiments. The dissociation of gases at

high temperatures limits the maximum pressure; consequently the higher the temperature the nearer do we arrive to the limit, and the greater is the interference due to dissociation. On the other hand, where the mixture is rich in gas the time for its inflammation is short. This would tend to increase the efficiency, whereas the influence of dissociation tends to diminish the efficiency."

Crastin's experiment

Crastin has made some experiments on the efficiency of acetylene as a motive power. The tests were carried out in a small Otto cycle engine, the revolutions being kept at 275 per minute. The ignition tube was heated from a separate supply, and was kept at the same temperature for both gases. The same quantity of each gas was used, namely 382 cubic inches, and they were both at the same pressure.

The following are the particulars of the tests:—

Diameter of cylinder . . .	1·5 inches.
Area of cylinder	1·767 inches.
Stroke of piston	2·5 inches.
Displacement by piston . .	4·417 cubic inches.
Clearance for firing chamber . .	1·0 inch.
Contents of firing chamber . .	1·767 cubic inches.
Compression	20 pounds.
Firing charges per minute . .	137·5.
Revolutions per minute . . .	275.

Results

ACETYLENE GAS.

Acetylene gas per minute . .	15·916 cubic inches.
Air supplied per minute . . .	591·490 ,, ,,
Proportion of air to gas . . .	37·16 to 1.
Hourly consumption of gas . .	0·552 cubic feet.
Pressure of gas as delivered to engine	0·6 inch.

COAL GAS.

Amount of coal gas per minute .	47·75 cubic inches.
Air supplied per minute . .	559·65 ,, ,,
Proportion of air to gas . .	11·72 to 1.
Hourly consumption of gas . .	1·658 cubic feet.
Pressure of gas as delivered to engine	0·3 inch.

From these results Crastin arrives at the conclusion that the efficiency of acetylene gas is three times greater than that of coal gas, but it must be observed that the volume of air used was far greater than one would expect to give the most effective working.

Neuberg on gas engine tests with Acetylene

Neuberg has pointed out that in the testing of a gas engine the following points must be considered:—

1. Testings of the value of the combustible material.

2. Tests of the work and other data afforded by the gas engine itself.

The heating power of the gas which is to be used as the motive power must first be ascertained, and this is best determined by the Junker calorimeter, the lower or "practical" result being taken for the calculation. This lower figure is taken because on account of the high temperature of the exhaust the water in the products of combustion cannot be condensed, but escapes as steam. The percentage of water must then be taken, and of the air and gas, and the quantity of water formed by the combustion must be calculated from chemical formulæ. The specific gravity of the gas must also be noted, using the Lux gas balance or the Bunsen apparatus. This concludes the first part of the test.

The time during which the tests with the gas engine are made is divided into intervals, say of five minutes. When a constant temperature has been obtained, readings must be taken every five minutes of—

Necessary data to note

1. The revolutions, as measured with a speed indicator.

2. The work done by the engine, using a Crosby indicator.

3. The quantity of gas consumed per interval is read off by a standard meter, the temperature and pressure of the gas being noted.

4. The quantity of air consumed per interval, together with the temperature and degree of exhaustion, must be noted.

5. The barometric readings must be taken.

6. The consumption of cold water per interval, and the temperature of the water at its entrance and exit.

7. The power given by the motor in brake horse power.

8. The waste gases of the exhaust must be analysed.

The series of experiments is complete when the above tests have been taken 12 times, *i.e.* for an hour.

Varying mixtures of gas and air should be used in separate experiments to form any idea of the capabilities of the engine.

As a result of many experiments, it may be stated that a Deutzer 6 H.P. gas-motor gave 28 per cent. efficiency; a Koerting 4 H.P. spirit-motor 25·5 per cent., whilst Krupp's petroleum Diesel motor gives 34 per cent.

Tests with Acetylene and with coal gas

In an engine made by Cuinat, the following tests were made to contrast the relative efficiency of coal gas and acetylene.

Tests were first made with coal gas to fix the consumption of gas per H.P. hour, and the results obtained were :—

Amount of coal gas per H.P. hour

Total consumption	1,380 litres.
Half pressure, 3 H.P. . . .	876 „
Full „ 6 „ . . .	516 „

The average pressure amounted to six atmospheres, the maximum being 17 atmospheres and the final 3·2 atmospheres.

The proportion of the mixture of acetylene to air used in the next experiments was fixed after trial at 1 to 20. The air valve required re-adjustment to give regular explosions.

Acetylene consumed per H.P. hour at 80 mm. pressure—

Total consumption	470 litres.
Half pressure	302 „
Full „	175 „

Amount of Acetylene per H.P. hour

1·8 atmosphere greater pressure occurred than in the case of coal gas, due, according to Cuinat, to the higher temperature in the cylinder. The acetylene explosion was much heavier. The maximum pressure was 29 atmospheres, the final pressure being one atmosphere less than with coal gas. The consumption of water is rather larger with acetylene.

Neuberg gives the following table of the relative prices, etc., of the various sources of power :—

Neuberg's table of the cost per H.P. hour with various substances

Material.	Unit.	Heating power. kg. calories.	Unit.	Price per H.P. hour.
Acetylene	cb. m.	12,161	126·1	23·7
Benzene	kg.	9,950	50·0	11·4
Spirit, 96 %	kg.	6,470	43·3	15·4
Oil, best	kg.	12,650	26·9	4·83
American oil	kg.	8,790	23·9	6·18
Russian oil	kg.	6,025	22·55	8·45

but it must be borne in mind that these are German prices, and would in no way represent the figures obtained in a country where good oil could be cheaply obtained.

In Germany acetylene motors are made by several firms, and Fig. 219 shows a type sold by the Allegemeine Carbid und Acetylen Gesellschaft, which in the illustration is working a small pump.

Where expense is not an object, or where the use of steam is inconvenient, the use of acetylene for small engines should prove a success. Besides the form of engine mentioned above, there are several others which give satisfactory results, whilst in

some forms a novelty is introduced by making the ignition of the mixture dependent on a spark from

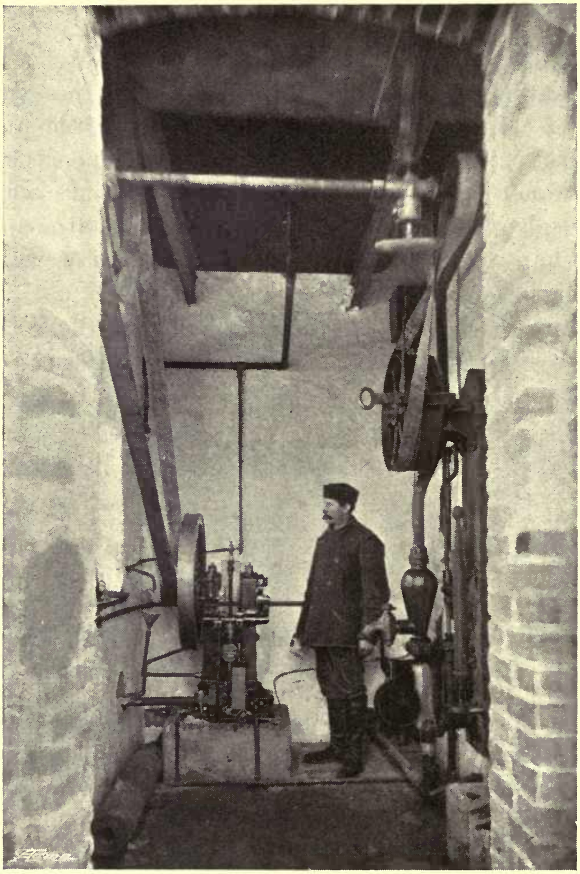


FIG. 219.—ACETYLENE ENGINE WORKING PUMP.

a small induction apparatus driven by the engine itself.

CHAPTER X

THE UTILISATION OF DILUTED ACETYLENE

The difficulty of properly burning Acetylene

THE trouble of consuming acetylene without smoking in the early days of its inception caused Dickerson and Suckert to attempt the combustion of acetylene diluted with air, and in 1894 it was in this way that the gas was consumed. But it was soon found that the cooling action of the nitrogen led to a considerable decrease in the illuminating power of the acetylene, although it enabled the acetylene to be burnt at a much larger burner, and so increased the illuminating effect.

American experiments on the candle power of mixtures of air and Acetylene

Experiments were made in America by Allan and Morehead to find the illuminating value of such a mixture, and also to determine the best proportions in which to mix the two gases. Their results are embodied in the two tables on the following page.

The first table gives the result as obtained with an ordinary standard Bray 00000 tip, such as is ordinarily used in the consumption of pure, or approximately pure, acetylene. The results obtained show conclusively that an admixture of air with acetylene, for any purpose whatever, is, in small quantities, exceedingly inefficient, and in large quantities quite out of the question where this form of burner is to be employed.

Candle Power of Acetylene and Air Mixtures.

Observations taken with Bray standard 00000 tip, consuming 1 cubic foot per hour.

Results obtained with small Bray union jet-burner

Per cent. of Air.	Per cent. Acetylene.	Difference.	Observed Candle Power.	Candle Power of mixture.	Difference.	Per cent. of Light.
0	100		48	240		100
1	99	1	45·5	228	12	95
3·5	96·5	2·5	38·71	193·55	34·45	80·64
5·5	94·5	2	36·75	183·75	9·80	76·56
6	94	·5	36·63	183·15	·60	76·39
9·5	90·5	3·5	33·76	168·80	14·35	70·33
15·0	85	5·5	29·14	145·70	23·10	60·70
17·5	82·5	2·5	27·21	136·05	9·65	56·68
20·5	79·5	3	22·97	114·85	21·20	48·27
23	77	2·5	20·81	104·05	10·80	43·35
26	74	3	18·23	91·15	12·90	37·97
29	71	3	16·47	82·35	8·80	34·31
32	68	3	13·27	66·35	16·00	27·64
34	66	2	11·28	56·40	9·95	23·50
40	60	6	6·92	34·60	21·80	14·41
46	54	6	3·4	17·45	17·15	7·27
51·5	48·5	5·5	1·3	6·60	10·85	2·75
59	41	7·5	·6	3·00	3·60	1·25
67·5	32·5	8·5	Starting-point of luminosity.			
78·5	21·5	11	Supports colourless flame.			
85·5	14·5	7	Just supports flame.			
89	11	3·5	Will not burn.			

Observation taken with Bray special slit high and low pressure tips.

Results obtained with Bray slit burner

Burner: Bray Slit.	Per cent. of Air.	Per cent. of Acetylene.	Rate of Consumption.	Observed Candle Power.	Candle Power of mixture.	Per cent. of Light given.	Per cent. of Light lost.	Per cent. Gas saved.	Per cent. net loss.
2 l.p.[1]	60	40	2·5	41·59[3]	83·18	34·65	65·35	60	5·35
2 h.p.[2]	56	44	1·8	34·78	96·60	37·62	62·37	56	3·75
3 l.p.	56·25	43·75	3	55·85	92·64	38·60	61·40	56·25	5·15
3 h.p.	56·25	43·75	2	38·11	95·27	39·69	60·30	56·25	4·06
4 l.p.	56	44	4	71·66	89·57	37·32	62·68	56	6·68
4 h.p.	57	43	3	48·61	81·01	33·75	66·25	57	9·25
7 l.p.	56	44	5	96·98	96·98	40·40	59·60	56	3·60
3 l.p.	50	50	3	66·67	111·11	46·29	53·71	50	3·71
3 l.p.	54·25	35·75	3	28·44	47·40	19·75	80·25	64·25	16·00
3 l.p.	40	60	3	71·87	119·78	49·90	50·10	40	10·10
3 l.p.	55	45	3	58·27	97·11	40·46	59·54	55	4·54
3 l.p.	50·6	49·4	3	66·10	110·16	45·90	55·10	50·6	3·50

[1] Low pressure. [2] High pressure. [3] Candle power of flame.

Conclusions arrived at

The second table gives the results as obtained with a Bray special slit burner. These burners were not constructed especially for acetylene, but were made for ordinary gas, and are used in photometric work, and for purposes where a high efficiency is desired, and the cost of the tip is immaterial. Any slit burner which is ordinarily used for city gas will burn the mixtures referred to in the table successfully and efficiently. As will be seen, the results obtained with these burners were very materially different from those obtained with the Bray 00000. With the slit union a mixture of acetylene and air, containing 66 per cent. or more of acetylene, causes smoking at the burner, and a mixture having 24 per cent. or less of acetylene will support only a non-luminous flame. The largest light and the highest efficiency is obtained with a mixture containing 52 per cent. of acetylene to 48 per cent. of air. A variation of 5 per cent. either above or below this figure, or a change to other burners having a larger or smaller capacity or rate of consumption, does not affect the efficiency to more than about 3 per cent. With this mixture a consumption of 5 cubic feet per hour can be maintained through a single burner, giving a single flame of 96·98 candle power, with a net loss of only 3·6 per cent. in the theoretical candle power of the pure gas.

Danger of using mixtures of Acetylene and air

At the time these experiments were made it was thought that the use of a mixture containing 50 per cent. of acetylene with an equal quantity of air was perfectly safe from explosion, but, as will have been seen from the experiments of Gerdes and others, a very serious risk was incurred, it becoming merely a question of the breadth of the delivery tubes and the rate of flow of the gas whether an explosive wave was propagated back to the mixing machine or not. It was on account of the danger of this that this process of burning it in America was abandoned.

Attempts to utilise such mixtures for village lighting

The idea has, however, cropped up from time to time, and in Europe as well as America has been to a certain extent used on a practical scale. Within the last few months the village of Hunmanby in Yorkshire was partly lighted by "electroid gas," which consisted of a mixture of one-third acetylene and two-thirds air; but the danger of such a supply, in view of the experiments made by Gerdes (page 127), was so great that the Home Office has issued an order prohibiting the use of such mixtures, whilst in America they are also forbidden under the fire insurance regulations.

Bullier suggests diluting Acetylene with other gases

The danger of diluting acetylene with air being so manifest, attempts have from time to time been made to dilute it with other gaseous material. In 1895 Bullier took out a patent for improvements in carburetting air and gas, in which he claims the use of acetylene for enriching water gas; whilst having then apparently found that acetylene was useless for this purpose, he, later on in the same year, took out a second patent for diluting it with nitrogen.

The result of diluting Acetylene with Water Gas

In America, where carburetted water gas forms so large a factor in the illuminating gas supply, attempts were made at an early date to use acetylene instead of oil gas for endowing the non-luminous water gas with illuminating power; but it was at once found that this could not be economically done, as the mixture of hydrogen and carbon monoxide acted so fatally on the illuminating power of the acetylene that the cost of the mixture would have been prohibitive.

Love's experiments on the candle power of mixtures of Acetylene and Water Gas

Dr. Love made a series of experiments on the enrichment of "blue," or uncarburetted water gas, by acetylene, and also on a poor carburetted water gas, with the following photometric results:—

Enrichment of Carburetted Water Gas

ACETYLENE AND UNCARBURETTED WATER GAS—LOVE.

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Water Gas.		
14·3	85·7	1·14	·0079
18·3	81·7	11·65	·633
19·0	81·0	12·44	·654
20·3	79·7	15·47	·762
21·1	78·9	18·68	·883
23·5	76·5	24·90	1·059
24·6	75·4	29·45	1·194
27·8	72·2	40·87	1·468
38·0	62·0	73·96	1·946

ACETYLENE WITH CARBURETTED WATER GAS—LOVE.

Analysis.		Illuminating power of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Water Gas Carburetted.		
4·5	95·5	22·69	2·17
9·4	91·6	29·54	2·04
11·2	88·8	35·05	2·05
15·0	85·0	42·19	2·03
21·4	78·6	52·61	1·95

Illuminating value of carburetted water gas, 13·5 candles.

These results show that whilst a non-luminous water gas would require the admixture of 24 per cent. of acetylene to yield a gas of the average illuminating power supplied in America, with a carburetted water gas the acetylene develops nearly its theoretical enrichment value.

The enrichment of Coal Gas by Acetylene

When acetylene was first introduced into England the gas manufacturers of the country were searching for something which should replace cannel coal—the price of which at that time had risen to a prohibitive point—as an enricher of poor coal gas, and the author

made an exhaustive series of experiments to see how far acetylene would answer for this purpose.

In order to ascertain the enrichment value of acetylene, coal gas, which had been stored in a holder for some time, and which had an illuminating value of 12 candles for 5 cubic feet, was employed. This gas from long standing might be considered to have deposited all condensible vapours, and was employed in order to prevent any question of vapour tension interfering with the results.

Importance of perfect mixing in testing enrichment values

In determining the illuminating value of mixtures of coal gas and enrichers, too little attention is, as a rule, paid to several very important points, chief amongst which are that the mixture shall be as nearly perfect as possible, and free from any stratification, and secondly, that the exact percentage of the enriching gas supposed to be present is really there, this latter being an especially important point when gases even slightly soluble in water are being used.

Method used in following experiments

In the following experiments, the method employed was to use a 5 cubic foot holder, the water of which was fairly saturated with hydrocarbons, and to run the 12 candle coal gas and the acetylene into this already roughly mixed, by passing them *pro rata* into a washbottle from which they travelled on together into the holder; thus, in making a mixture which was to contain 10 per cent. of acetylene, with 90 per cent. of coal gas, the flow of gas and acetylene into the washbottle was so arranged that 4½ cubic feet of coal gas were passed through the bottle, entering it by one tube, whilst ½ a cubic foot of acetylene passed in through the second tube.

Prevention of stratification in the gas

The mixture when made was allowed to stand over night in order to allow diffusion to perfect the mixture, and a long series of experiments shows that this effectually prevented any stratification of the gases, the acetylene, however, being slightly soluble in water,

the lower portion of the mixture in contact with the water would occasionally contain a trace less acetylene than the portion near the top of the holder, and to overcome this trouble the mixture was analysed as it left the burner at the commencement of the experiments, whilst a second analysis was taken also from the burner at the conclusion of the experiments, the mean of these two analyses giving the composition of the mixture dealt with.

Standard used in testing the illuminating power of the mixture

In taking the illuminating power Dibdin's 10 candle pentane argand was used as the standard, and the mixture was burned in the London argand with a 3-inch flame. The rate of flow having been noted, the illuminating power was calculated to a consumption of 5 cubic feet, whilst the illuminating value was also determined in a set of Bray's union jet burners, the richer mixtures being burnt in the sized burners which gave a slightly smoky flame at ordinary pressures, the pressure being then increased until the flame ceased to smoke, whilst in each case the pressure at which the test was made was noted.

Burners used to consume the mixture

With illuminating values up to 20 candles, the London argand gave the best results, but above that, as might be expected, the flat flame burners developed the highest illuminating power; indeed, a limit was soon reached at which it was impossible to use a 3-inch flame in the argand.

In every case the highest illuminating value recorded—each being a mean of 10 readings—was taken as the illuminating power of the mixture. An example of one test will suffice to make this method of determination clear, and although the method is laborious, it is the only one which can be relied upon to yield results of any value.

Analysis of the Mixture.

	Commencement of test.	End of test.	Mean.
Acetylene . .	17·0	16·5	16·75
Coal gas . . .	83·0	83·5	83·25
	100·0	100·0	100·00

Example of method employed to determine illuminating value

Burner used.	Illuminating power per 5 cubic feet.	Pressure. Inches.	Remarks.
London Argand	26·2	3/10	
Flat flame No. 9 Bray	Smokes	8/10	
No. 9 „	32·7	12/10	
No. 8 „	32·8	12/10	Shows a tendency to smoke
No. 7 „	34·3	12/10	
No. 6 „	36·1	12/10	
No. 5 „	34·5	12/10	
No. 4 „	34·5	12/10	
No. 4 „	34·7	9/10	
No. 4 „	34·3	6/10	
No. 3 „	34·1	12/10	
No. 2 „	32·3	12/10	

Therefore a No. 6 Bray, with a pressure of 12/10, gives the value of mixture 36·1.

$$\frac{36{\cdot}1 - 13}{16{\cdot}75} = 1{\cdot}36 \text{ enrichment value.}$$

Working in this way the following values were obtained :—

Enrichment value of Acetylene for Coal Gas

Percentage composition of mixture.		Illuminating value.		Enrichment value of 1 per cent in candles.
Coal gas.	Acetylene.	Coal gas.	Mixture.	
99·1	0·9	13	13·9	1·00
97·9	2·1	3	15·1	1·00
96·0	4·0	13	17·3	1·07
95·2	4·8	13	18·4	1·12
91·0	9·0	13	23·5	1·16
89·5	10·5	13	25·3	1·17
85·0	15·0	13	33·0	1·33
83·25	16·75	13	36·1	1·36
66·9	33·1	13	60·5	1·43
55·5	44·5	13	76·7	1·43
16·7	83·3	13	175·2	1·94
00·0	100·0		240·0	2·40

Showing that for small enrichments of illuminating value acetylene has an enrichment value of only a little over 1 candle for each per cent. of acetylene added, so that with oil at a reasonable price, it could not compete with oil gas for this purpose.

Enrichment researches

The author was much impressed by the fact that the enrichment value of the acetylene when mixed with the coal gas, although only about half as great as would be expected on theoretical grounds, yet was enormously higher than when the acetylene was diluted with hydrogen, and a research was made to ascertain the illuminating value obtained from the acetylene when it was diluted with the various gases which could be employed for this purpose.

In making these experiments, all the precautions employed in determining the enrichment value of acetylene with coal gas were observed, and the figures given in the following tables were arrived at in the same way.

Acetylene and Hydrogen.

The enrichment value of Acetylene for Hydrogen

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Hydrogen.		
8·3	91·7	*nil*	*nil*
16·3	83·7	18·2	1·11
25·7	74·3	37·0	1·44
26·6	73·4	40·0	1·50
37·7	62·3	62·1	1·65
52·7	47·3	92·0	1·74
78·7	21·3	153·4	1·94
87·0	13·0	177·5	2·04
100·0	0·0	240·0	2·40

Acetylene and Carbon Monoxide.

Enrichment value of Acetylene for Carbon Monoxide

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Carbon monoxide.		
14·3	85·7	*nil*	*nil*
18·3	81·7	8·0	0·43
26·0	74·0	28·1	1·08
37·2	62·8	51·8	1·39
46·3	53·7	74·4	1·60
63·3	36·7	109·6	1·75
79·3	20·7	146·5	1·84
90·0	10·0	187·0	2·05
100·0	0·0	240·0	2·40

Acetylene and Carbon Dioxide.

Enrichment value of Acetylene for Carbon Dioxide

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Carbon dioxide.		
26	74·0	2·8	0·10
32	68·0	9·4	0·20
45·1	54·9	27·2	0·60
46·0	54·0	28·4	0·61
60·6	39·4	64·1	1·05
79·2	20·8	110·8	1·39
100·0	0·0	240·0	2·40

Acetylene and Nitrogen.

Enrichment value of Acetylene for Nitrogen

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Nitrogen.		
4·0	96·0	Will not burn	*nil*
13·7	86·3	Not measurable	*nil*
28·5	71·5	19·5	0·68
38·7	61·3	39·0	1·00
46·0	54·0	58·0	1·26
63·0	37·0	98·3	1·56
74·9	28·1	131·1	1·75
100·0	0·0	240·0	2·04

Acetylene and Methane.

Enrichment value of Acetylene for Methane

Analysis.		Illuminating value of the mixture.	Enrichment value of Acetylene for 1 per cent.
Acetylene.	Methane.		
7·2	92·8	15·6	2·16
15·4	84·6	29·5	1·91
18·0	82·0	38·0	2·11
25·4	74·6	54·0	2·12
31·1	68·9	64·5	2·07
36·3	63·7	76·0	2·09
44·5	55·5	94·0	2·11
50·0	50·0	104·5	2·09
55·3	44·7	114·0	2·06
61·5	38·5	130·0	2·11

It is evident from these experiments that methane is the only diluent capable of developing the wonderful illuminating value of acetylene when it is utilised for enrichment, and they also show that it is to the presence of methane in the poor coal gas and carburetted water gas that the enrichment caused by small additions of acetylene is due.

Percy Frankland's researches on the effect of diluents on illuminating power

In 1884 Percy Frankland[1] made a research upon the influence of the various gases which constitute coal gas upon the illuminating value of ethylene, the presence of which was then considered to be the cause of the luminosity of coal gas. The results which he obtained are summarised in the following tables.

Action of combustible diluents

COMBUSTIBLE DILUENTS.

Diluents.	Percentage of ethylene.	Percentage of diluents.	Candle power per 5 c. ft. per hour.
Hydrogen	77·55	22·45	54·58
	68·39	31·61	49·37
	53·58	46·42	39·21
	35·47	64·53	30·85
	26·08	73·92	22·84
	13·37	86·63	6·73
	10·0	90·0	0·00
Carbon monoxide	81·65	18·35	55·27
	57·75	32·25	47·73
	46·30	53·70	33·09
	37·94	62·06	26·52
	28·73	71·27	13·16
	23·89	76·11	6·56
	20·0	80·0	0·00
Methane	85·67	14·53	57·91
	69·09	30·91	47·88
	57·74	42·26	40·42
	35·90	64·10	33·17
	13·00	87·00	19·35
	7·87	92·13	17·59

[1] *Chem. Soc. Journ.*, xlv. 30, 227.

Effect of non-combustible diluents on the illuminating power of Ethylene

Non-Combustible Diluents.

Diluent.	Percentage of ethylene.	Percentage of diluent.	Candle power per 5 c. ft. of gas.
Carbon dioxide	93·68	6·32	55·52
	90·59	9·41	51·81
	89·03	10·97	49·98
	81·73	18·27	42·81
	70·75	29·25	33·23
	64·14	35·85	26·52
	52·94	47·06	14·72
	45·61	54·39	7·49
	40·0	60·0	0·00
Nitrogen	84·69	15·31	51·96
	71·12	28·88	39·58
	59·93	40·07	29·64
	47·08	59·92	20·81
	36·24	63·76	11·82
	28·81	71·19	7·20
Oxygen	82·57	17·43	70·93
	80·67	19·33	72·53
	75·51	24·49	74·19
	68·50	31·50	71·17
	60·69	39·31	explosion
Air	79·68	20·32	54·45
	67·15	32·85	45·84
	55·92	44·08	37·16
	42·69	57·31	26·78
	33·91	66·09	16·22
	22·31	77·69	0·61
	13·31	86·69	explosion

Similarity of results obtained by diluting Acetylene and Ethylene

On comparing these results with those obtained with acetylene, it will be at once seen that they are similar in character, and that for small quantities of the enricher it is methane, and methane only, that brings out the illuminating value.

Experiments made by the author also clearly show that even when methane is diluted with other combustible diluents, such as hydrogen or carbon

monoxide, until there is only 30 per cent. to 40 per cent. of it present, it is still capable of developing considerable illuminating value for enrichers mixed with it, so that although 12 per cent. of acetylene mingled with a mixture of 50 per cent. of hydrogen and 50 per cent. of carbon monoxide only gives 1 candle of light, the same quantity with a mixture of 33 per cent. hydrogen, 33 per cent. carbon monoxide, and 33 per cent. methane yields over 30 candles.

Action of Methane

The action of diluents on gases of high illuminating power is a subject not only of great practical importance, but also of great theoretical interest.

Flame temperature and its importance

There is not the least doubt that the temperature of a flame plays a most important part in governing the luminosity of the carbon particles, the incandescence of which gives it the power of emitting light, and at first sight the higher thermal value of methane as compared with equal volumes of hydrogen and carbon monoxide appears an ample explanation of the fact that it is so far their superior in developing the illuminating power of small percentages of enriching gas.

Heat evolved by burning combustible diluents

The researches of Favre and Silbermann show that the combustion of one molecule volume of each of these three combustible diluents yields the following thermal results:—

Hydrogen . . .	68·942	thermal units.
Carbon monoxide .	67·284	„
Methane . . .	209·008	„

So that the total heat generated by a methane flame might be imagined to be three times as great as of a flame of either hydrogen or carbon monoxide consuming the same volume of gas in the same period.

Experiment, however, shows that if equal volumes of these three gases be consumed in the same burner, the size of the flame produced is very different. In order to determine this they were each burnt at the

rate of 5 cubic feet per hour from the same argand burner, so that the height of the flame should give the ratio of flame area.

Height of flame given by the combustion of equal volumes of—

Height of flame given by the combustion of equal volumes of combustible diluents

	mm.	inches.
Hydrogen	25	1·0
Carbon monoxide	56	2·25
Methane	107	4·25

The flames so produced were, however, so different in shape, owing to the argand flame not being a true cylinder, that another experiment was then made to see the rate of flow necessary to give a 3-inch flame in the London argand, the pressure in each case being equal:—

Rate of flow needed to give equal sized flames

Hydrogen	9·5 c. ft. per hour.
Carbon monoxide	7·3 ,, ,,
Methane	3·0 ,, ,,

Under these conditions the flame surface was the same in each case, and if the thermal value of equal volumes be multiplied by the respective consumption of gas, it should give an idea of the relative ratio of temperature existing in the flame:—

Probable ratio of development of heat in the flames

Hydrogen	$68{,}924 \times 9·5 = 654{,}778$
Carbon monoxide	$67{,}284 \times 7·3 = 491{,}173$
Methane	$209{,}008 \times 3 \quad = 627{,}024$

So that if it were the temperature of the flame alone that governed the luminosity of mixtures of an enricher with these diluents, one would expect methane and hydrogen to give practically the same result when used in this way, whilst carbon monoxide would always give very inferior results.

The combustion of Methane and its illuminating value

When methane is burnt at the end of an open tube or in a flat flame burner, it is practically non-luminous, but when consumed in a London argand, in which the flame is at a higher temperature, at the rate of 5 cubic feet per hour, it becomes slightly luminous, and emits

between 5 and 6 candle-power, whilst if the flame be raised to a still higher temperature in a regenerative burner, the candle-power is still further increased. Gas withdrawn from the flame shows that the luminosity is due to the formation of acetylene by the baking action of the flame walls on the methane in the non-luminous zone.

Cause of the loss of luminosity with Hydrogen as a diluent

If now a mixture of pure hydrogen and 10 per cent. of acetylene be burned in an argand or other burner, a non-luminous flame is obtained, and if gas be withdrawn from the flame at the point where luminosity commences in an ordinary flame, no trace of acetylene can be detected, showing that it has all been consumed in the lower part of the flame without decomposition of the acetylene molecule, whilst on increasing the percentage of acetylene in the mixture until it can be detected at this point in the flame, luminosity at once appears.

Cause of the superiority of Methane as a diluent

This makes the cause of the superiority of methane over hydrogen as a diluent fairly clear, as it evidently acts in protecting and probably reinforcing the acetylene molecules in their passage through the non-luminous zone of the flame, until the temperature is sufficient to cause their sudden decomposition with evolution of light.

Temperature needed to bring about the luminous decomposition of Acetylene at various degrees of dilution

The luminous decomposition of acetylene requires a higher and higher temperature to bring it about the greater the dilution, and as far as it has been possible to carry the experimental results, pure acetylene decomposes with evolution of light at 780° C., whilst each increase of 10 per cent. in dilution raises the necessary temperature by 100° C., Fig. 220, so that a flame from a mixture containing 80 per cent. of hydrogen and 20 per cent. of acetylene only attains the necessary temperature—over 1,600° C.—near the top of the flame, and the non-luminous zone is in consequence very large, whilst the temperature necessary to bring

about this action with pure acetylene is only 780° C., so that the non-luminous zone nearly disappears. It must also be remembered that owing to the changes due to heat in the non-luminous zone, and combustion without decomposition, and therefore without emission of light, the original acetylene present in the gaseous mixture supplied to the burner is reduced to about one-tenth of its volume before luminosity is reached.

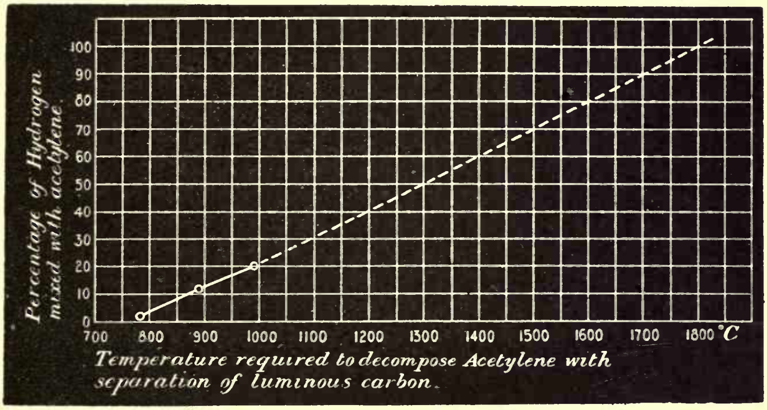


FIG. 220.

The utilisation of Acetylene diluted with oil gas for railway carriage lighting

At the present time the only direction in which diluted acetylene has achieved a marked success is in the utilisation of mixtures of acetylene with oil gas for railway carriage lighting, and it is estimated by the best authorities that in Germany alone over 7,000 tons of carbide will be required during 1900 for the generation of the gas for this purpose.

Compressed Acetylene for railway carriage lighting

Before it was realized that there was any danger in using undiluted acetylene compressed in cylinders for railway lighting, experiments were made with it for this purpose on one of the chief northern lines, a composite coach being lighted by it with magnificent effect, two one-foot burners being employed in the

compartments and one half-foot burner in the lavatories.

American experiments on the use of the gas

These experiments were at once discontinued when the result of compression on the propagation of explosion in acetylene became known; but recent experiments in America have led to its being introduced there on the Great Northern Railway line, and after running a sleeping car for some months, with cylinders of the Pintsch type containing acetylene compressed at 150 pounds, it is decided to equip several entire trains with the light. The system used is due to Lipschutz and Toltz, who construct the cylinders and high-pressure pipes in such a way that in case of a car catching fire the seams fuse at 260° C. (500° F.), and the pressure is relieved long before the detonating point of the gas is reached. The lamps are specially made to take their air supply from without, and to get rid of the hot products of combustion without heating the gas supply.

System introduced

Attempts to introduce automatic generators for carriage lighting

There is a wide field for undiluted acetylene for this purpose when once the danger of compression is successfully got over, as a cylinder of acetylene would last three times as long as one of oil gas, and give a far better illumination. Many attempts have been made to fit railway carriages, trams, etc., with small automatic generators, and experiments are still being vigorously pushed in this direction; but the constant attention required, and the trouble of frequent cleaning and recharging, lead those best able to judge to the conviction that such a system is very unlikely to prove successful.

Gerdes' researches on the alleged dangers of Acetylene for this purpose

It was in 1896 that, mixtures of acetylene with oil gas having been suggested for this purpose, Gerdes, the chief engineer to Messrs. Pintsch, of Berlin, made a most thorough investigation of the dangers alleged to exist in connection with its use, and to determine under what conditions it could be safely employed,

and his results were communicated to the Berlin Institute of Mechanical Engineers on December 1, 1896.

In the first part of his paper he dealt with the formation of explosive compounds by the union of acetylene with copper and its alloys, and also with the temperature developed during the generation of the gas, and then gives the results of his experiments on cylinders of compressed acetylene and mixtures of oil gas and acetylene in order to ascertain if explosion could be induced under conditions that might possibly occur in railway-carriage lighting.

Possible temperatures and pressures developed by the decomposition of Acetylene

He says: "As already stated, acetylene gas decomposes into its constituent elements, hydrogen and carbon, at a temperature of 780° C., and the development of heat per gramme molecule of acetylene amounts to 26 grammes of 47·77 calories. If the specific heat of carbon is taken at a very high temperature, as 0·46, and of hydrogen at a constant volume, as 2·4, the temperature of decomposition of acetylene will be—

$$\frac{47 \cdot 770}{2 \cdot 2 \cdot 4 + 24 \therefore 0 \cdot 46} = 3{,}016° \text{ C.}$$

The specific heat of carbon varies, as is well known, according to the temperature, but the figures assumed are approximately correct. From the above calculated temperature of decomposition, the increase of tension may be calculated at 12·05 atmospheres absolutely, presuming the gas to have had an initial pressure of one atmosphere, and a pressure of 132·55 atmospheres if the gas was under an absolute initial pressure of 11 atmospheres.

This calculation makes no claim to absolute accuracy, such calculation being hardly possible, because absolutely correct figures relative to the specific heat particularly of carbon cannot be obtained. Another presumption in the above calculation is that the whole quantity of acetylene is decomposed instantaneously.

Experiments to ascertain how far these calculations were borne out by practice

The firm of Messrs. Pintsch has made a number of experiments in order to find out how far these calculations are correct in practice, and what dangers are involved in the employment of acetylene for lighting railway passenger carriages.

In the first place, a soft-soldered receiver, such as generally employed by the Prussian State and other railways, was filled with acetylene compressed to six atmospheres and heated on a wood fire. The result was that the recipient became leaky at 200° C. or thereabout, the melting point of the tin and lead alloy, the tin melted, and the acetylene escaped at the leaks and burnt in the ordinary manner.

Conditions under which compressed Acetylene in soldered receivers can be made to explode

If, therefore, receivers of this kind are employed, the use of pure acetylene would not be accompanied by any danger; subsequently, however, it was proved that acetylene will explode in receivers of this kind if a pipe connected to the receiver is heated to the temperature necessary for the decomposition of acetylene.

The propagation of explosion through pipes

A brazed cylinder was then filled to six atmospheres and placed on a fire, so that the seams and cocks were not in contact with the flames. This receiver exploded with a tremendous report, and was blown to pieces, as shown in Fig. 221. Another experiment was then made with regard to the propagation of the decomposition of acetylene through pipe systems. A receiver was filled to six atmospheres with acetylene and provided with a pipe of 5 metres interior diameter, and 2 metres in length. At a point about a metre and a half from the receiver the pipe was heated by means of a water gas flame, and as soon as the pipe began to get red hot, the recipient exploded, being blown entirely to pieces.

Pure compressed Acetylene condemned for carriage lighting

Under these circumstances the employment of pure acetylene gas for illuminating purposes, especially for railway cars, in which case the gas must necessarily be employed under pressure, appeared too dangerous. In

order, however, to render the high illuminating power of acetylene employable for this purpose, the firm decided to make a number of experiments in order to find means for reducing or entirely obviating the above-mentioned danger, and these experiments showed that acetylene when not compressed will decompose, but that the explosion caused thereby is not nearly so violent as when the gas is compressed.

Effect of pressure on the decomposition

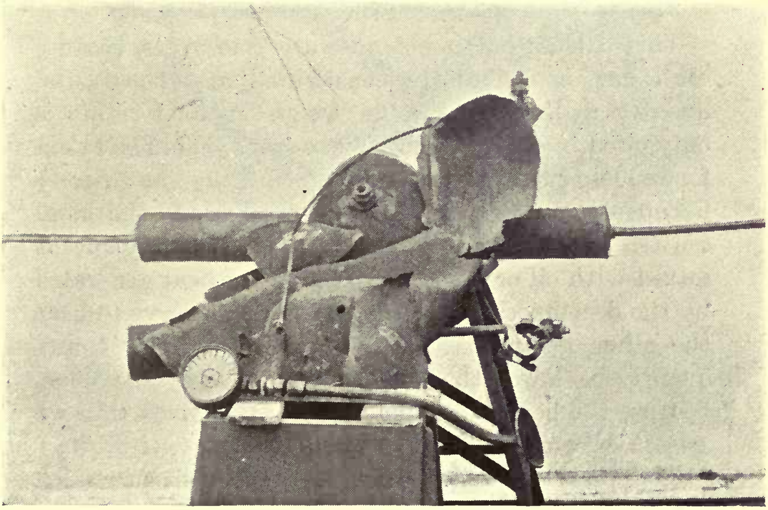


FIG. 221.

Thus the above-mentioned calculation would only be correct for highly-compressed acetylene, whilst at low pressure, apparently owing to slow decomposition and simultaneous cooling during the reaction, the tension after the reaction is considerably less than would appear from these calculations. If acetylene and oil gas are mixed and the specific heat of oil gas assumed as 0·4 and its specific weight as 0·75, and that of acetylene taken as 0·91, in a mixture of 30

Possible temperatures and pressures developed by

the explosion of mixtures of oil gas and Acetylene

volumes of acetylene and 70 volumes of oil gas a rise of temperature of—

$$\frac{47{\cdot}770}{2 \cdot 2{\cdot}4 + 24 \cdot 0{\cdot}46 + \frac{0{\cdot}75 \cdot 7}{0{\cdot}91 \cdot 3} \cdot 26 \cdot 0{\cdot}4} = 1{,}330^\circ$$

will take place, from which it will be seen that an initial pressure of 7 atmospheres absolute would produce an increase of pressure, taking the initial temperature at 0, of pt. $\frac{273 + 1{,}330 \cdot 7}{273} = 41$ atm.

This calculation is not absolutely accurate, because each gas is differently constituted and has consequently a different specific weight; the formula is only cited in order to show what steps should be taken for reducing the danger or rendering the gas entirely harmless. As will be readily understood, the final tension is considerably reduced if the acetylene is mixed with oil or other gas, because the heat generated by the decomposition of acetylene has to serve to heat the other gas also. The temperature must consequently be lower than in the case of acetylene alone, because the heat generated is divided between the two gases.

Influence of dilution

Practical experiments

The practical experiments in this respect, which were in part carried out in the presence of Director Borck, of the State Railway Management, of Berlin, are shown by the tables, and prove sufficiently for practical purposes that the employment of a mixture of 30 per cent. acetylene and 70 per cent. oil gas or coal gas for railway carriage lighting involves no danger whatever, because the increase of temperature will never be sufficient to burst the receiver. These receivers will stand a much higher pressure than that caused by the decomposition of a 30 per cent. mixture of acetylene, even under the most unfavourable circumstances. This, as previously remarked, is due to

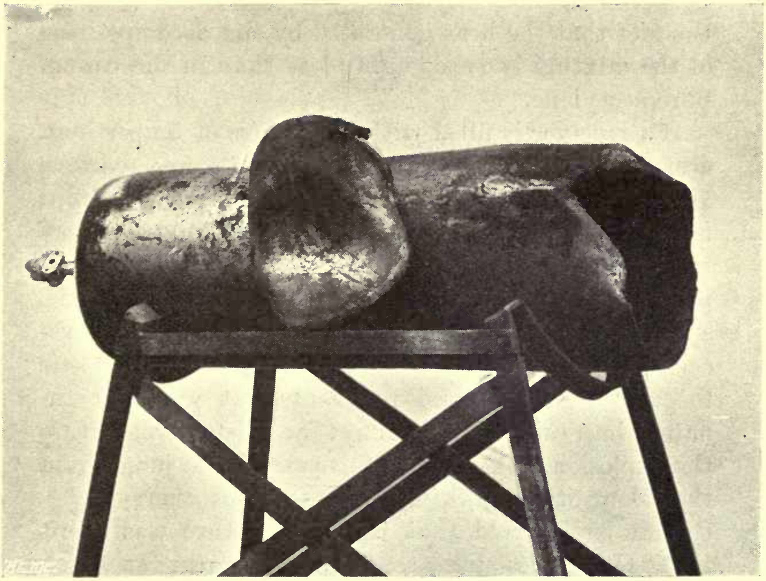


FIG. 222.—EXPERIMENT 1. *See Table, page* 642.

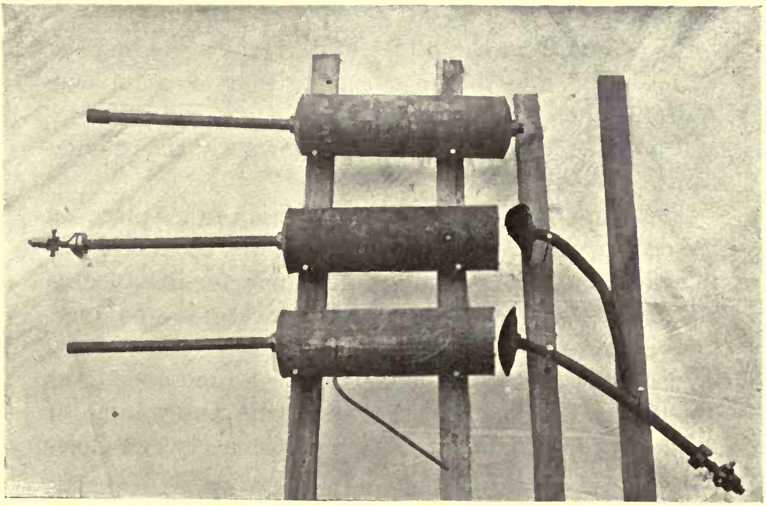


FIG. 223.—EXPERIMENTS 20, 21 AND 24. *See Table, page* 643.

the fact that the heat generated by the decomposition of the mixture is considerably less than in the case of pure acetylene.

Behaviour of mixtures of equal volumes of Acetylene and oil gas

If a receiver is filled with a mixture of 50 per cent. acetylene and 50 per cent. oil gas, and connected to a ¾ inch pipe, also filled with the mixture, and the pipe is then heated, experiments have shown that even when the pipe has been heated to a very high temperature the mixture in the receiver will not explode, and can only be caused to explode by heat in the receiver itself. In this case it would be perfectly safe to employ soft-soldered recipients. It was unfortunately impossible to determine at what temperature the explosion took place in this case, but to judge from the colour of the glowing pieces—bright cherry red—it may be inferred that the temperature was about 1,000° C. Lewes states that the temperature at which acetylene with 50 per cent. hydrogen decomposes is about 1,250° C. In any case the temperature was considerably higher than that at which pure acetylene exploded.

Approximate temperature necessary to cause explosion

Pressures caused by the decomposition of 30 percent. Acetylene with oil gas

As is seen from the tables of the trials, the increase of pressures due to the decomposition of a mixture containing 20 to 30 per cent. acetylene is insignificant, and much less in practice than shown by the calculations.

The same increase of pressure which takes place on the decomposition of acetylene would also occur on heating almost any other kind of gas, such, for instance, as oil gas, or even air, but in the latter cases it would not take place so rapidly, because the whole volume of gas is not capable of absorbing the heat from outside as quickly as the heat generated within the volume of gas owing to the decomposition of the acetylene molecules.

Perfect safety of a mixture of

This shows that if a mixture of acetylene and oil gas is employed and the percentage of the former does

not exceed 30 per cent. no danger whatsoever can be incurred in connection with railway trains, because in this case an explosion cannot be transmitted to the receivers by the pipe system. If in order to produce or cause the decomposition of the acetylene in a mixture of this kind it is necessary to heat the receiver to 1,000° C. as has been shown, it may be safely asserted

30 per cent. Acetylene with oil gas

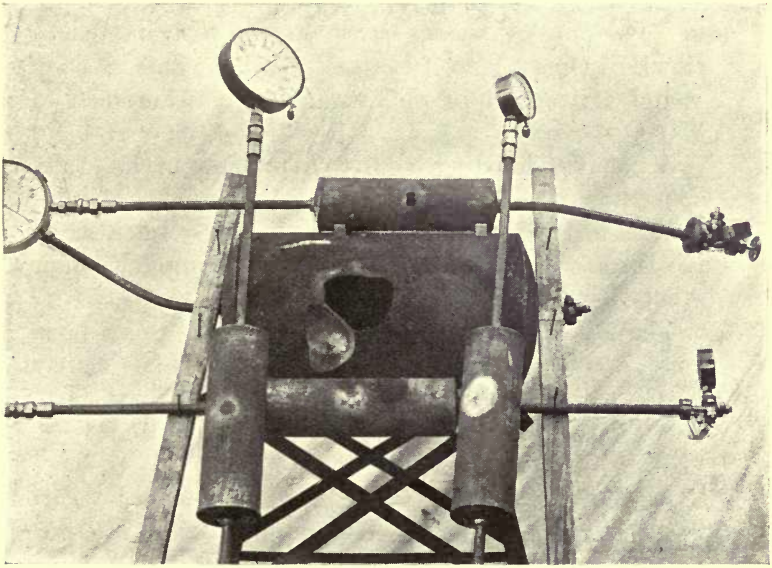


Fig. 224.—Experiments 27, 31 and 32. *See Table, page* 644.

that a point is attained at which the mixture of acetylene and oil gas involves no greater danger than the employment of oil gas alone or of compressed air. At a temperature of 1,000° C. the initial tension of the volume of gas or air contained in the receiver will have risen several times higher than the initial pressure in consequence of the heating of the gases in the receiver; according to whether the latter has been heated over a large or small fire, and the gases are

Behaviour of cylinders of the compressed mixture under the influence of heat

entirely or only partially heated. Then, again, the gas receiver, if it became red hot at any point, would burst, and the gas would escape at the fracture before the acetylene would have time to decompose, because the temperature would not have reached a sufficient height to effect the decomposition. Experiments have shown this assumption to be correct.

Comparison of the behaviour of the mixture and of air under the same conditions

The tables show that a receiver filled with 80 per cent. oil gas and 20 per cent. acetylene, at a pressure of seven atmospheres, burst on the tension being slowly increased to 16 atmospheres. This tension would correspond to an average increase of heat of 350° C.

A receiver filled with air to a pressure of 11 atmospheres burst on the tension having been slowly increased to 18 atmospheres. Both the above-mentioned receivers were heated over a fire throughout their whole length.

Pressures to which the cylinders are tested

These receivers, when tested, have to stand a pressure of 40 to 50 atmospheres, so that they had evidently been heated at some points to such an extent as to deteriorate the material to the above-mentioned degree.

As a matter of fact, the joints of an ordinary carriage receiver would have been melted and the gas have escaped long before the above-mentioned mean temperature of 350° C. would have been attained.

Effect of pressure on explosion in small pipes

In connection with the experiments as to the explosive power, it is singular that the explosion in small pipes of 25 to 30 mm. diameter, the gas not being compressed, is not so violent as in connection with larger receivers and compressed gas. Berthelot seems to have had the same experience, since he states that the higher the tension is the shorter will be the duration of the reaction in comparison with a lower tension (see page 85).

Effect of rate of flow on

If acetylene gas at ordinary burning pressure is

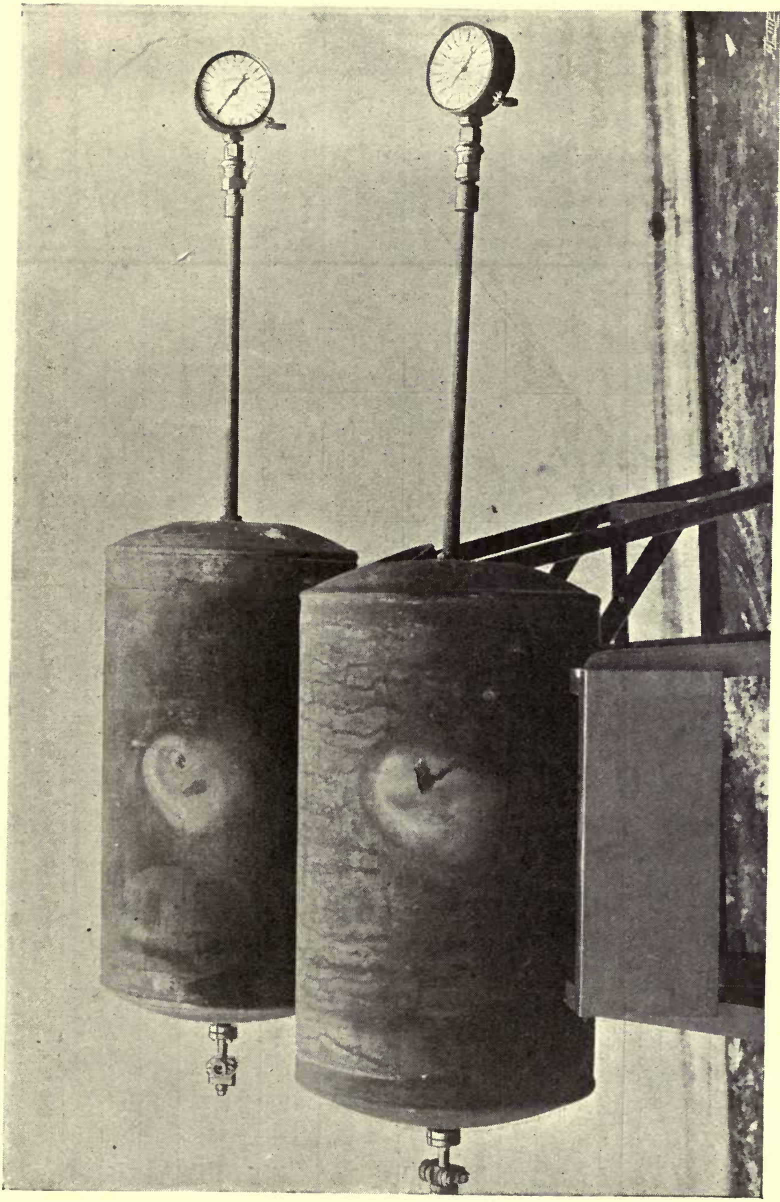


FIG. 225.—EXPERIMENTS 29 AND 34. See Table, page 644.

TABLE I. *Trials as to the explosive power of Acetylene.*

No. of Experiment.	Kind of Receiver Employed.	Means of Heating same.	Proportion of Mixture, percentage in volumes.	Initial Pressure.	Pressure immediately preceding decomposition.	Pressure immediately after decomposition.	Remarks.
No. 1	Brazed Gas receiver. Length =1000 mm. Diam. =360 mm. Contents=101·8 lit.	The whole receiver heated over a wood fire.	100 Acetylene.	Kilo pr. sq. cm. 7·8	Kilo pr. sq. cm. —	Kilo pr. sq. c.m. —	One end of receiver blown out (Fig. 222).
2	Soft soldered and rivetted receiver. Length =1800 mm. Diam. =420 mm. Contents=249·3 lit.	do.	do.	8·2	—	—	Solder melted in the longitudinal and transverse seams; the Gas burnt out.
3	Brazed Gas receiver. Length =800 mm. Diam. =420 mm. Contents=110·8 lit.	A pipe of 5 mm. internal diam. and $2\frac{1}{2}$ mm. metal, heated by a water gas flame.	do.	7·2	—	—	The point at which pipe was heated was $1\frac{1}{2}$ metre from recipient. The latter was entirely blown up (Fig. 221).
4	Steel Flask. Contents=15·85 lit.	do.	do.	7·8	—	36	Point at which the pipe was heated was 1 metre from the steel flask.
5	Steel Flask. Contents=15·85 lit.	$\frac{3}{4}$ in. gas pipe heated by water gas flame.	do.	7·0	—	34	Decomposition took place in two minutes.
6	Steel Pipe. Length =500 mm. Interior dia.=$1\frac{1}{2}$ in.	Heated by a water gas flame.	do.	7·0	10·5	23	
7	do.	do.	do.	3·0	—	4·2	
8	do.	do.	do.	2·2	—	—	
9	do.	do.	do.	2·0	—	4·0	
10	do.	do.	do.	2·0	—	3·2	
11	do.	do.	do.	2·0	2·9	4·2	
12	do.	do.	do.	1·8	2·8	4·0	

Trials as to the explosive power of Acetylene.—Continued.

No. of Experiment.	Kind of Receiver Employed.	Means of Heating same.	Proportion of Mixture, percentage in volumes.	Initial Pressure.	Pressure immediately preceding decomposition.	Pressure immediately after decomposition.	Remarks.
No. 13	Receiver Length =480 mm. Diam. =160 mm. Contents=9·75 lit. with $\frac{3}{4}$ in. pipe attached.	Heated by a water gas flame.	100 Acetylene.	Kilo pr. sq.cm. 1·2	Kilo pr. sq. cm. —	Kilo pr. sq. c.m. 3·6	
14	do.	do.	do.	2·0	4·5	16	
15	do.	do.	do.	1·2	—	3·2	
16	do.	do.	do.	2·0	3·2	23	Pressure in 5 min.=2·5 Atm. " 10 " =3·0 " " 20 " =3·0 " " 23 " =3·2 " then rapid rise to 23 atmospheres and decrease to 4·2 atmospheres (absolute pressure.)
17	do.	do.	do.	3·0	—	21	
18	do.	do.	do.	5·0	—	29	
19	do.	do.	do.	7·6	—	—	Blown up.
20	do.	$\frac{3}{4}$ in. pipe heated by a water gas jet flame.	80 Acetylene. 20 Oil Gas.	7·6	—	—	Exploded (Fig. 223).
21	do.	Receiver heated by a water gas jet flame.	50 Acetylene. 50 Oil Gas.	12·5	—	80	Burst and burned till gas was consumed (Fig. 223).
22	do.	$\frac{3}{4}$ in. pipe heated by a water gas jet flame.	do.	9·8	—	—	Valve melted off; gas burned out.
23	do.	First the $\frac{3}{4}$ in. pipe, then the receiver, heated by a water gas jet flame.	do.	11·0	—	69	On heating the $\frac{3}{4}$ in. pipe no decomposition took place.
24	do.	$\frac{3}{4}$ in. pipe heated by a water gas jet flame.	75 Acetylene. 25 Oil Gas.	8·0	—	—	Exploded (Fig. 223).

Trials as to the explosive power of Acetylene.—Continued.

No. of Experiment.	Kind of Receiver Employed.	Means of Heating same.	Proportion of Mixture, percentage in volumes.	Initial Pressure.	Pressure immediately preceding decomposition.	Pressure immediately after decomposition.	Remarks.
No. 25	Receiver. Length =480 mm. Diam. =160 mm. Contents=9·75 lit. with $\frac{3}{4}$ in. pipe attached.	First the $\frac{3}{4}$ in. pipe, then the receiver, heated by a water gas jet flame.	50 Acetylene. 50 Oil Gas.	Kilo pr. sq. cm. 7·0	Kilo pr. sq. cm. 13·5	Kilo pr. sq. c.m. 66	Circular pieces of metal torn out on heating the $\frac{3}{4}$ in. pipe. No decomposition took place.
26	do.	$\frac{3}{4}$ in. pipe heated by a water gas jet flame.	40 Acetylene. 60 Oil Gas.	7·5	—	—	No explosion.
27	do.	Receiver heated by a water gas jet flame.	40 Acetylene 60 Oil Gas.	7·0	—	43	(Fig. 224.)
28	Gas Receiver. Length =900 mm. Diam. =480 mm. Contents=162·9 lit.	do.	50 Acetylene. 50 Oil Gas.	7·0	—	—	Pieces of plate 200 mm. in diameter torn out. At the part heated the metal was reduced by stretching from a thickness of 3 mm. to 1 mm.
29	do.	do.	40 Acetylene. 60 Oil Gas.	7·0	—	—	Bulged out at the point heated, and gas burned out at fracture at said point (Fig. 225).
30	Gas Receiver. Length =1800 mm. Diam. =480 mm. Contents=325·8 lit.	The whole receiver heated by a wood fire.	40 Acetylene. 60 Oil Gas.	7·2	—	—	Receiver burst by a gradual explosion, and was deformed, no parts being blown out.
31	Receiver. Length =485 mm. Diam. =160 mm. Contents=9·75 lit.	Receiver heated by a water gas jet flame.	$33\frac{1}{3}$ Acetylene. $66\frac{2}{3}$ Oil Gas.	7·0	—	17	Bulge at the part heated, with short longitudinal cracks (Fig. 224).
32	do.	do.	30 Acetylene. 70 Oil Gas.	7·0	—	17	Do. (Fig. 224).
33	do.	do.	40 Acetylene. 60 Oil Gas.	7·2	—	12	Receiver remained apparently uninjured.
34	Receiver. The same as No. 28.	do.	30 Acetylene. 70 Oil Gas.	9·5	—	17	Bulged out and gas burned out (Fig. 225).
35	Gas Receiver. The same as No. 30.	The whole receiver heated by a wood fire.	20 Acetylene. 80 Oil Gas.	7·1	16	No decomposition took place.	Blown to pieces.
36	do.	do.	100 Air	11·0	18	do.	Do.

Trials as to the explosive power of Acetylene.—Continued.

No. of Experiment.	Kind of Receiver Employed.	Means of Heating same.	Proportion of Mixture, percentage in volumes.	Initial Pressure.	Pressure immediately preceding decomposition.	Pressure immediately after decomposition.	Remarks.
37	Brazed Receiver. Length =485 mm. Diam. =160 mm. Contents=97·5 lit.	Receiver heated by a water gas jet flame.	100 Acetylene.	Kilo pr. sq.cm. 1·6	Kilo pr. sq. cm. 3·4	Kilo pr. sq. c.m. 2·1	
38	do.	do.	do.	1·2	3·2	2·7	
39	do.	do.	do.	1·2	3·6	3·0	
40	do.	do.	do.	1·3	3·8	3·0	
41	do.	do.	do.	2·0	16·0	8·0	
42	do.	do.	do.	2·2	13·0	5·9	
43	do.	do.	do.	2·0	11·0	5·5	
44	do.	do.	do.	2·7	16·0	6·0	
45	do.	do.	do.	2·0	12·0	6·0	
46	do.	do.	do.	3·0	21·0	7·0	
47	do.	do.	do.	3·0	21·0	7·0	
48	do.	do.	do.	3·1	22·0	7·1	
49	do.	do.	do.	3·0	20·5	6·8	
50	do.	do.	do.	3·0	20·0	6·7	
51	do.	do.	do.	4·0	40·0	10·0	
52	do.	do.	do.	4·1	32·0	8·0	
53	do.	do.	do.	4·1	33·0	8·1	
54	do.	do.	do.	4·1	(13·0)	(3·2)	
55	do.	do.	do.	3·8	30·0	7·9	
56	do.	do.	do.	5·3	54·0	10·0	
57	do.	do.	do.	4·8	(23·0)	(5·0)	
58	do.	do.	do.	5·0	49·0	9·8	
59	do.	do.	do.	5·0	49·0	9·8	
60	do.	do.	do.	5·2	53·0	10·2	

the rapidity of de-composition

slowly passed through an open glass tube, and the latter heated to the temperature of decomposition, the acetylene will be observed to give a black deposit or to polymerise at the heated point according to the temperature, without, however, exploding. This is apparently due to the fact that the gas following keeps the place cool to a certain extent.

If, on the other hand, a closed tube be employed and heated to 780°, sudden decomposition, accompanied by sudden increase in pressure, will take place.

Considera-tion of the best conditions under which to use Acetylene for carriage lighting

The question now to be considered is: How can acetylene be most advantageously employed for illuminating railway carriages with a view to the greatest possible safety, and due regard being had to the present prices of gas and acetylene?

Table II. gives the photometric values of a series of mixtures of acetylene and oil gas, containing various percentages of acetylene, which would recommend themselves to consideration in connection with the above question. The table also contains various proportions of acetylene and coal gas mixtures.

Tem-perature of ignition of mixtures of air and Acetylene

The employment of a mixture of acetylene and air is precluded, because such mixture involves greater danger than would be incurred by the employment of pure acetylene, the temperature of ignition of acetylene mixed with 35 per cent. of air being, according to Le Chatelier, 480 in a large room.

High enrichment value of Acetylene on poor oil gas

A mixture of acetylene with oil gas—particularly of an inferior quality—as will be seen from the table, shows an enormous increase in the illuminating power, which is increased to about three times the original power. The table shows the amount to which the illuminating power is increased in connection with each sort of burner separately, as no standard figures could be arrived at. Thus, for instance, a small burner is less advantageous for a lighter gas than a large one, whilst a large burner cannot be employed at all for a

heavy gas. The photometric tests were intentionally conducted with the classes of burners now generally in use for lighting railway carriages, no special burners being employed. Each burner was adjusted to produce a full flame without considering the pressure at which the gas burned, and without taking into consideration the question as to whether the size of the flame was the most advantageous possible with regard to the consumption of gas and the illuminating power.

Description of the photometric methods employed

It will be further seen from the table that the admixture of a greater percentage of acetylene does not show a proportionately favourable increase of illuminating power. In view of the fact that it is just the inferior sort of oil gas which would be improved first of all, the inferior kind now very commonly used, and that a mixture of this gas with 20 per cent. of acetylene—burnt through a No. 40, the burner now most in use on the railway systems—will increase the lighting power to three times its present value, it will be acknowledged that such an increase of lighting power will represent a tremendous progress in railway carriage lighting.

The most economical mixtures to use

Pure coal gas cannot be photometrically measured in the small oil gas burner, because it burns through these burners with a blue flame; but on mixing 30 per cent. of acetylene with the coal gas a considerable increase in the illuminating power of the flame was attained through various oil gas burners, further particulars of which are shown at end, Table II. This table shows further that a mixture of 30 per cent. of acetylene and 70 per cent. of coal gas showed an illuminating power equal to that of oil gas when burnt alone.

The use of Acetylene diluted with coal gas for railway carriage lighting

If, therefore, the railways employ a mixture of coal gas and acetylene, they would be able to attain a light about equal to oil gas lights in a very simple manner by merely putting up an acetylene generator and suitable means for compressing gas at such points

TABLE II. *Photometric tests with pure Acetylene and mixtures of the same with other gases.*

	Kind of Burner.	No. of Burner.	Gas Pressure in Millimètres.	Gas consumed per hour in litres.	Candle Power.	Gas consumption per candle per hour in litres.	Average Gas consumption, per candle power, per hour in litres.	Proportion of the light power of mixture, to that of pure gas oil.	Remarks.
Pure Oil Gas compressed to 10 Atmospheres.	Bray Burner.	00	34	73·5	16·6	4·42	7·66		
		000	30	48	6·89	6·96			
		0000	28	39	3·26	11·6			
	Ordinary Oil Gas Burner.	15	21	19	1·6	11·80	7·11		
		30	14	21·5	2·94	7·31			
		40	15	33	6·7	4·92			
		60	25	60	13·4	4·40			
90 per cent. Oil Gas. 10 per cent. Acetylene.	Bray Burner.	00	34	73	34·7	2·10	3·31	2·09	
		000	30	48·5	15·3	3·17		2·22	
		0000	28	36	7·7	4·66		2·36	
	Ordinary Oil Gas Burner.	15	21	17·5	3·6	4·86	3·24	2·25	
		30	13	21	6·7	3·13		2·27	
		40	15	33	12·6	2·61		1·88	
		60	25	62	26·6	2·33		1·98	
80 per cent. Oil Gas. 20 per cent. Acetylene.	Bray Burner.	00	42	82	56·2	1·45	2·02	3·38	
		000	35	54	28·3	1·31		4·92	
		0000	35	43·3	16	2·71		4·90	
	Ordinary Oil Gas Burner.	15	24	21	7·25	2·89	2·06	4·53	
		30	15	22	10·5	2·09		3·57	
		40	16	33·5	20·2	1·65		3·01	
		60	33	73	45·2	1·62		3·37	
70 per cent. Oil Gas. 30 per cent. Acetylene.	Bray Burner.	00	55	92	59·9	1·54	1·83	3·60	
		000	44	60	34·5	1·75		5·00	
		0000	40	42·5	19·3	2·20		5·92	
	Ordinary Oil Gas Burner.	15	24	19	8·52	2·23	1·87	5·32	
		30	16	22	11·6	1·89		3·94	
		40	15	33·5	19·4	4·72		2·89	
		60	38	69·5	42·5	1·63		3·17	

Photometric tests with pure Acetylene and mixtures of the same with other gases.—Continued.

	Kind of Burner.	No. of Burner.	Gas Pressure in Millimètres.	Gas consumed per hour in litres.	Candle Power.	Gas consumption per candle per hour in litres.	Average Gas consumption, per candle power, per hour in litres.	Proportion of the light power of mixture, to that of pure gas oil.	Remarks.
60 per cent. Oil Gas. 40 per cent. Acetylene.	Bray Burner.	00	55	83·7	66·1	1·27	1·43	3·98	
		000	44	58	40·25	1·19		5·26	
		0000	40	45	24·5	1·84		7·51	
	Ordinary Oil Gas Burner.	15	24	19	10·27	1·85	1·59	6·41	
		30	16	21·5	13·5	1·59		4·59	
		40	15	33	21·9	1·5		3·26	
		60	81	68·25	47·5	1·43		3·54	
50 per cent. Oil Gas. 50 per cent. Acetylene.	Bray Burner.	00	55	89·66	68·55	1·31	1·41	4·10	
		000	45	57	40·25	1·41		5·84	
		0000	40	42·5	28·2	1·51		8·65	
	Ordinary Oil Gas Burner.	15	25	20·5	10·8	1·89	1·57	6·75	
		30	16	23	13·8	1·67		4·69	
		40	16	35	24·1	1·45		3·59	
		60	31	63	49·5	1·27		3·69	
Pure Acetylene.	Bray Burner.	00	85	10·3	16·7	0·61	0·61	10·06	
		000	85	73·5	12·6	0·58		18·28	
		0000	85	57	88·5	0·64		27 14	
	Ordinary Oil Gas Burner.	15	29	19	23·8	0·79	0·81	14·87	
		30	18	21·5	26	0·82		8·84	
		40	—	—	—	—	—		
		60	—	—	—	—	—		
70 per cent. Coal Gas. 30 per cent. Acetylene.	Ordinary Oil Gas Burner.	15	50	26·5—27	2·71—3·4	7·94—9·78	8·86		
		30	30—35	32·25—36·25	5·82—8·87	5·54—6·17	5·85		
		40	30	46—46·5	10·83—13	3·54—4·29	3·91		
		60	25	50—62	19·5—21·5	2·74—3·18	2·96		
		X	12	31·5—36	11·8	2·67—3·05	2·86		

where coal gas is now to be had, thus forming a charging station for the railway carriages.

Method of making the mixtures

The mixture of acetylene with oil or coal gas is effected by coupling two gas meters in the desired relative proportions, feeding the gases separately to each meter, and combining the systems at the rear of the meters where the combined gas is drawn off by pumps. In order to prevent the vibration from the pumps being communicated to the gas-meters, a concussion box is inserted in the system, as in the case of gas motors.

Present railway lamps and fittings available for Acetylene mixtures

Lamps, regulators, and in fact all the fittings now applied in connection with the lighting of railway carriages may remain unaltered.

Attempts have been made to determine by experiment to what extent acetylene gas works, connected up by pipe systems to private houses, would be liable to explosion by fire caused in any one of the houses to which the works are connected, or in the event of the pipe system being accidentally heated to the temperature necessary for causing decomposition of the gas.

The propagation of explosion in pure Acetylene under practical conditions of town distribution

In order to ascertain this a gasholder was filled with acetylene, and the gas blown out through a one-inch pipe. The gasholder was again filled with pure acetylene, and the pipe leading to it heated to a temperature exceeding that at which acetylene decomposes, at a distance of one and a half metres from the gasholder, the pipe being heated to white heat, without, however, causing the propagation of the decomposition to the holder.

The introduction of mixtures of oil gas and Acetylene into England

In consequence of the great Continental success of the admixture of 20 per cent. acetylene with oil gas, application was lodged at the Home Office, by Mr. F. G. Worth, to sanction such a mixture in England under the ordinary railway carriage cylinder pressure of 10 atmospheres. The safety of the mixture, and of mixtures considerably richer in acetylene,

was completely established by a series of tests carried out in the presence of the Home Office officials, and in consequence, by an order of the Secretary of State, dated March 28th, 1898, a mixture of oil gas with 20 per cent. of acetylene is allowed to be used at a pressure not exceeding 150 lb. on the square inch.

Photometric experiments on the value of mixtures of oil gas and Acetylene in England

In order to determine the increase in illuminating power given by various percentages of acetylene in oil gas, and whether the mixture could be employed with economy, the following experiments were instituted by the author. Oil gas containing 20 per cent. of acetylene was compressed into a cylinder under a pressure of 10 atmospheres, some of the orginal oil gas being also compressed in a second cylinder to the same pressure. Both cylinders were then blown off to 5·8 atmospheres, and the illuminating power of each was taken under identical conditions. The burner used was a "40 litre" one, and the results were as follows:—

Results

		Illuminating Value.	
Pressure.	Gas Consumption.	Oil Gas.	Oil Gas and Acetylene.
5·8	1 cub. ft.	7·4	15·6

An analysis of the gas showed that the mixture contained 22 per cent. of acetylene, although but 20 per cent. was originally added, the increase being due to the loss of some of the oil gas, in which, under pressure, some of the vapours of benzene and toluene condense to the liquid state. Working from these figures it will be seen that the addition of 22 per cent. of acetylene caused an increase of illuminating power of 110 per cent., or 100 per cent. with 20 per cent. of acetylene.

Composition of the mixed gases

ANALYSIS OF MIXTURE OF OIL GAS AND ACETYLENE.

Acetylene	22·0
Hydrogen	11·6
Saturated hydrocarbons	40·9
Unsaturated hydrocarbons	22·5
Carbon dioxide	0·5
Carbon monoxide	0·0
Nitrogen	2·0
Oxygen	0·5
	100·0

The value of original oil gas and the mixture of oil gas with acetylene were next determined, photometrically, in an ordinary railway carriage lamp, at angles below the horizontal, on the Dibdin radial photometer.

Conditions of lighting in a railway carriage

An ordinary railway carriage is from 5 ft. to 5 ft. 9 in. in width, and 8 ft. from door to door, whilst the flame is as a rule about 7 ft. from the floor, the seats being from 15 in. to 17 in. in height, which would bring the paper or book one was trying to read as nearly as possible 3 ft. from the floor. This gives an angle of from 45 to 55° as the important one for the rays which are to be utilised.

Illuminating value of oil gas at angles below the horizontal

OIL GAS.

Angle.	Pressure.	Gas.	Candles.	Candles per cub. ft.
Horizontal	1·0	2·0	7·4	3·7
10	—	—	8·0	4·0
20	—	—	8·2	4·1
30	—	—	8·2	4·1
40	—	—	8·2	4·1
50	—	—	8·0	4·0
60	—	—	7·6	3·8
70	—	—	7·8	3·9
80	—	—	8·0	4·0

Average candles per cub. ft., 3·9.

OIL GAS AND ACETYLENE.

Illuminating value of mixed oil gas and Acetylene at angles below the horizontal

Angle.	Pressure.	Gas.	Candles.	Candles per cub. ft.
Horizontal	1·0	2·0	17·0	8·5
10	—	—	17·0	8·5
20	—	—	17·5	8·75
30	—	—	18·0	9·0
40	—	—	17·0	8·5
50	—	—	17·0	8·5
60	—	—	17·0	8·5
70	—	—	16·5	8·25
80	—	—	16·5	8·25

Average candles per cub. ft., 8·5;

showing that the addition of 22 per cent. of acetylene increases the illuminating power of the oil gas by over 110 per cent. at all angles.

These figures show therefore that the addition of the 20 per cent. of acetylene doubles the illuminating value of the oil gas.

The economic value of mixtures of oil gas and Acetylene

With regard to cost, as we have before seen, acetylene, at the present price of carbide, will cost about £1 18*s.* to £2 per 1,000 on the holder, and 200 cub. ft. will accordingly cost 7*s.* 8*d.* The compressed oil gas costs from 6*s.* to 12*s.* per 1,000. With oil gas at 8*s.* per 1,000, 800 cub. ft. will cost 6*s.* 5*d.*, so that the total cost of 1,000 cub. ft. of the enriched gas will be 14*s.* 1*d.*; but as the illuminating value of the mixture is double that of the plain oil gas, there is an economy of 1*s.* 11*d.* per 1,000. As the oil gas is dearer, the saving will be greater, and *vice versâ*, so that with cheap oil gas the addition of acetylene would not pay. With oil gas at 6*s.* 6*d.* per 1,000 there is practically no difference; but the advantages accruing from the use of acetylene would make the mixture more desirable than the plain gas. Amongst the advantages are these—that the cylinders would last for double the length of time they would with

The advantages of using en-

riched oil gas for carriage lighting

the oil gas with the same charge, and there would not be so much formation of liquid hydrocarbons, due to compression, with consequent revaporizing when the pressure is reduced, thus causing inequality in the illuminating power.

There are other fields, however, where, in the future, diluted acetylene may play an important part.

Necessity for enrichment with coal gas

In large towns like London, where the Gas Companies have to supply a gas of specific illuminating power, and where the gas is continually subjected to photometric tests at stations spread over the whole area supplied, any deficiency in the lighting power of the gas being visited with rigorously enforced penalties, enrichment in some form or other becomes a practical necessity. In London the gas has to have an illuminating power of 16 candles, and in order to ensure this over the enormous area supplied, the gas must be sent out from the works testing up to 17 to 17·5 candles. With sea-borne Durham coals of the character largely used in the Metropolis for gas-making, the illuminating value of the gas will be about 15 candles, but as the Act which governs the gas supply of London enforces the illuminating value of 16 candles, whilst in many other towns the standard is still higher, the gas manager has to enrich the gas by from $1\frac{1}{2}$ to 2 candles before he can with safety send it out for distribution. This enrichment may be done in several ways—

Methods of enrichment employed with coal gas

1. By the admixture of a certain percentage of cannel coal with the original coal.
2. By carburetting the coal gas with the vapours of volatile hydrocarbons.
3. By oil gas.
4. By mixing the coal gas with carburetted water gas.

And it is evident that if acetylene could be produced at a reasonable cost, the ease of its production, and freedom from all risk of condensation, taken in con-

junction with its wonderful illuminating power, would make it the enricher *par excellence* of the future.

In many localities, however, the grade of coals required for making the coal gas is very dear, with the result that the price of the coal gas is almost prohibitive; and if in such places some other diluent than coal gas could be found for acetylene, it would at once command a large and lucrative field of operation.

A great field for diluted Acetylene

This is even more the case on the Continent than in England, and many hundreds of small towns and villages, which are at present without a gas supply, offer a boundless field for any system which will yield an ordinary illuminating gas for distribution at a reasonable price, the utilisation of pure acetylene being limited and hampered by its cost. Many suggestions have been made and experiments tried in order to ascertain how best to dilute the acetylene, whilst at the same time keeping the illuminating value up to that of a rich coal gas; but they have all failed, from the causes enumerated in the earlier part of this chapter.

The necessity for having a certain proportion of methane in any diluting gas for use with Acetylene

It is clearly shown by the experiments on enrichment, given on pages 624, 625, that in order to develop the illuminating value of the acetylene in gaseous mixtures, it is absolutely necessary to have present a certain percentage of methane in the diluting gas, and the author has always felt that if such a gas could be rapidly and cheaply made it would open up a wide field of utility for the acetylene.

Method for cheaply making a diluent for Acetylene

If superheated steam be injected into a mass of incandescent carbon, the mixture of carbon monoxide and hydrogen, known as water gas, is produced. This is useless as a diluent for acetylene, as it requires the addition of a large percentage before any luminosity is developed; but if tar, crude oil, or any other form of cheap hydrocarbon be steam-injected into the

fuel a few inches below its surface, the water gas produced forms a skin round the hydrocarbon spray and protects it from complete decomposition into carbon and hydrogen, large volumes of methane, the most stable of the compounds of hydrogen and carbon, being produced.

The gas so generated consists of a mixture of carbon monoxide, hydrogen, and methane, with small quantities of impurities, the following analysis giving an idea of its composition:—

Composition of the diluting gas

Hydrogen	51·8
Carbon monoxide	14·2
Methane and other hydrocarbons	31·4
Carbon dioxide, etc.	2·6
	100·0

and extended working with a plant capable of making 200,000 cub. ft. a day showed that the gas could be made at a cost of 8*d*. per 1,000 on this scale. A large company, making their own carbide, could make an initial profit of over £4 a ton by taking concessions for the lighting of small towns and debiting the works with the carbide at £12 per ton.

The cost of Acetylene for diluting by such a gas

A ton of good carbide yields 11,000 cub. ft. of acetylene, so that it costs, say, 25*s*. per 1,000 when labour and charges on plant are allowed for.

The diluting gas has an initial illuminating power of 8 to 10 candles per 5 cub. ft., and the addition of 6 to 7 per cent. of acetylene to it brings it up to a good 18 candle gas, splendidly adapted for burning alone in flat flames or argands, for cooking or for incandescent mantles, and having nearly the same specific gravity, rate of flow through mains, etc., as coal gas, and being perfectly permanent, showing no condensation or loss of illuminating power in cold weather.

	£	s.	d.
200,000 cub. ft. of diluting gas, at 8*d*. per 1,000, costs	6	13	4
13,000 cub. ft. of acetylene, at 25*s*. per 1,000, costs	16	5	0
	£22	18	4

213,000 cub. ft. of 18-candle gas costs £22 18*s*. 4*d*., or 1,000 costs 2*s*. 2*d*. in the holder. Allowing 10*d*. a 1,000 for distribution and capital charges, this gas could be sold at 4*s*. a 1,000, leaving a profit of 1*s*. per 1,000. The economic conditions of such a gas supply

In the experiments on which these figures are based the fuel employed in the generator was poor gas coke at 10*s*. per ton and crude oil at 2*d*. per gallon, and it was found that a 10- to 12-candle power gas made on the same scale cost 9½*d*. to 10½*d*. per 1,000, yielding a proportionately higher illuminating power when enriched by the same quantity of acetylene. Where anthracite is cheap, as in the South Wales district, this would be found far better than coke.

Taking the English Gas Companies—

The charges for Coal gas in England

31	Companies	charge	less than 2*s*. 6*d*. per 1000 c. ft. for gas.
104	,,	,,	from 2*s*. 6*d*. to 2*s*. 11*d*.
331	,,	,,	,, 3*s*. 0*d*. to 3*s*. 11*d*.
381	,,	,,	,, 4*s*. 0*d*. to 4*s*. 11*d*.
326	,,	,,	,, 5*s*. 0*d*. to 5*s*. 11*d*.
139	,,	,,	,, 6*s*. 0*d*. to 6*s*. 11*d*
48	,,	,,	,, 7*s*. 0*d*. to 7*s*. 11*d*.
20	,,	,,	,, 8*s*. 0*d*. to 8*s*. 11*d*.
13	,,	,,	over 10*s*.

So that even amongst existent Companies there is ample scope for some such process, should the production of carbide reach an output that left a surplus over the demand.

The generation of diluted acetylene from mixed carbides

Carbide of aluminium is decomposed by warm water with evolution of methane, whilst under the same circumstances carbide of manganese yields a mixture of methane and hydrogen; and in 1896 the author

proposed the use of carbide of calcium, mixed with carbide of aluminium or carbide of manganese, to generate diluted acetylene in ordinary generators, the heat evolved by the decomposition of the calcium carbide decomposing the others. He also pointed out that by mixing black oxide of manganese and excess of carbon with the carbide material in the electric furnace a saving of electrical energy could be obtained and a mixed carbide produced, which, by evolving diluted acetylene, would do away with the trouble of smoking at the burner.

Disposal of the lime residue from acetylene installations

The introduction of acetylene installations on a large scale at once brings into prominence the trouble of dealing with the lime residue from the generator. At first it was hoped that this would prove valuable as a manure; but in practice it has been found that in the condition of semi-sludge in which it leaves the generator the water present contains some acetylene in solution, and this has an injurious effect on plant life, whilst, as it holds excess of water for a considerable time, its weight adds to the expense of cartage. The best way to treat it, where space is available, is to leave it on the ground until air-dried and weathered, after which it can be used on clay soil with advantage. In installations in small country houses where cesspool drainage is used it can be put direct into the cesspit, upon which it has a sweetening influence, and renders the deposit, when judiciously used, of manurial value.

CHAPTER XI

THE ANALYSIS OF MATERIAL FOR CARBIDE MANUFACTURE AND OF CARBIDE AND ACETYLENE

Importance of chemical analysis in Carbide manufacture

AS our knowledge of the importance of using pure material in the manufacture of calcium carbide has increased, the necessity for definite knowledge as to the composition of the material, and the importance of constant analyses of the ingredients employed, and of the carbide produced, has been more and more realised.

Varying qualities of Carbide produced, and importance of proper blending

In a well-arranged carbide factory, not only should every fresh consignment of lime and coke be analysed, but the carbide before packing should be sorted and blended with the same care that is bestowed on a modern prism powder. Hardly any works produce a uniform quality of carbide. In running furnaces, the run or tapped carbide, and the ingot removed from the furnace when it has become too choked to run, vary considerably in their gas-yielding properties; whilst with ingot furnaces several grades of carbide are formed, varying from the 99 per cent. carbide in the centre of the ingot to the 30 per cent. crust near the exterior; and unless proper blending is resorted to in order to give a constant quality for distribution, discontent is soon manifested by the consumer, who does not fail to notice that on several occasions a charge of carbide in his generator nearly fills the

holder with gas, whilst on another day the same quantity of material barely gives half the yield.

Before purification was introduced, the carbide maker, knowing that directly the phosphuretted hydrogen in the gas rose above 0·1 per cent. a haze would be formed in any small ill-ventilated rooms in which the gas was burnt, felt the importance of pure material in order to keep below this limit; but now that the blame can be passed on to there being no purifier used, or to its being ineffective, there is the risk that in view of the increasing difficulty of obtaining good carbonaceous material for the carbide manufacture, and the high price of good lime in some localities, the precautions may be relaxed.

Causes tending to the use of inferior material in Carbide making

In describing the analytical processes that may be used by those interested in carbide and acetylene, it will be well to commence with the crude materials.

The Analysis of Coke or Coal.

Analysis of coke

Sampling.—The whole value of the analysis as representing the average quality of a consignment depends upon this operation, and during the unloading of the barge or truck, pieces should be taken at frequent intervals from the mass; these can then be roughly broken down and mixed, portions being again taken from every part of the mixture. These portions are finely ground, and the powder spread in a layer on clean glazed paper, and about 300 grams taken from various parts of the spread-out mass with a spatula, and placed in a well-ground stoppered bottle, carefully labelled to denote origin and date of arrival.

Taking a sample for analysis

It is best to sieve the powdered coke through a wire sieve of small mesh, about 90 to the inch, and take only the portion which passes through for the analysis.

Determinations required

In the coke analysis for carbide manufacture, the following may be estimated—water (moisture), ash,

sulphur, phosphorus, carbon. In the ash, silicic acid and magnesia may also be determined.

Should an analysis of an anthracite or coal which it is proposed to coke for carbide manufacture be desired, in addition to the above estimations, the amount of volatile matter should also be determined.

The estimation of moisture (a) in coke

Determination of moisture.—About 2 or 3 grams of the finely powdered coke are heated in a weighing tube in an air bath, first at 110° C. for one or two hours, and then at 200° C. till the weight is constant. The difference gives the amount of moisture contained in the coke.

Generally it is most convenient to carry out the operation in a platinum crucible, since the same sample may afterwards be used for the determination of the ash.

(b) in coal

In the case of coal, the air bath should not be heated above a temperature of 105° C. and the crucible and contents must be weighed at intervals, since after a time an increase of weight is often found. The lowest result must always be taken for calculating the loss due to moisture.

Determination of volatile and combustible matter in coal.—Place the crucible and dried coal over the bunsen flame and raise it to a bright red heat, care being taken that the crucible lid fits. After heating in this way for three minutes, transfer to the blowpipe and heat strongly for the same period, not allowing the crucible and contents to cool between the heatings. Cool in desiccator and weigh.

Estimation of the volatile matter only approximate

Various methods have been proposed for this estimation, but on the whole the above gives the best results. It cannot, however, be regarded as giving more than an approximation of the coke yield which may be expected in any type of oven. Under the same treatment, moreover, different estimations made with the same sample of coal often vary somewhat;

therefore it is advisable in important cases to make more than one estimation.

Determination of ash

Determination of the ash.—The dried coke, from the estimation of moisture, or the coal after treatment for volatile matter, is heated directly over the bunsen flame, in the platinum crucible with the lid removed, until the carbon is completely burnt away. The action is accelerated by placing the crucible well on its side, and from time to time giving it a gentle turn so that a fresh surface may be exposed. After cooling and weighing, add a small quantity of alcohol, when any unburnt carbon will float. Should indication be given that the combustion has not been complete, evaporate the alcohol and again ignite.

Example.—Moisture, volatile matter and fixed carbon, and ash of coal.

Calculation of results

Moisture.	Platinum crucible and coal .	43·8156 gr.
	„ „ „ cover .	41·8561
	Coal . .	1·9595

Weight of crucible at intervals—
43·7758
43·7743
43·7723
43·7747

Crucible and coal	43·8156
Lowest weight of crucible and coal .	43·7723
Moisture	0·0433

$$\text{Moisture per cent.} \quad \frac{0{\cdot}0433 \times 100}{1{\cdot}9595} = 2{\cdot}20 \text{ per cent.}$$

Volatile matter.	Platinum crucible and dry coal	43·7723
	„ „ „ coke .	43·6073
		0·1650

$$\text{Volatile matter per cent.} \quad \frac{0{\cdot}1650 \times 100}{1{\cdot}9595} = 8{\cdot}42 \text{ per cent.}$$

or 100 parts of coal lose 8·42 + 2·20 = 10·62;
then 100 − 10·62 = 89·38 = coke yield.

Ash.	Crucible, cover, and ash . .	42·0620
	„ and cover . . .	41·8561
		0·2059

$$\text{Ash per cent} \quad \frac{.0{\cdot}2059 \times 100}{1{\cdot}9595} = 10{\cdot}50 \text{ per cent.}$$

Determination of total sulphur.—One gram of the very finely powdered coke is mixed with one gram of magnesia and 0·5 gram of sodium carbonate in a platinum crucible with a glass rod. The crucible is heated for an hour so that only the bottom is red hot. After the coke is burnt the residue is of a brownish colour. This is put into a beaker with water, and bromine water added until the liquid becomes yellow. It is then boiled until the yellow colour disappears, and filtered. The bromine must be free from sulphur. The filtrate is made acid with hydrochloric acid, and whilst boiling is precipitated with hot barium chloride solution, the precipitate so obtained being then washed and ignited.

Estimation of Sulphur

The amount of sulphur is calculated from the barium sulphate obtained.

Calculation of the percentage of Sulphur from the weight of Barium Sulphate

$$BaSO_4 : S$$

$$233 : 32 = BaSO_4 \text{ found} : x$$

$$x = \frac{32 \times BaSO_4 \text{ found}}{233}$$

$$x = 0{\cdot}1373 \times BaSO_4 \text{ found}$$

P = quantity of coke used.

$$P : 0{\cdot}1373 \times BaSO_4 \text{ found} = 100 : x$$

$$x = \frac{13{\cdot}73 \times BaSO_4 \text{ found}}{P} = \text{per cent. of sulphur.}$$

Example—

Quantity of coke taken = 1·1720 gr.

$BaSO_4$ found = 0·0610 gr.

$$x = \frac{13{\cdot}73 \times 0{\cdot}0610}{1{\cdot}172} = 0{\cdot}715 \text{ per cent. sulphur.}$$

Determination of phosphorus.—The phosphorus is best estimated in the ash. A sufficient quantity, say 10 grams of coke, is first incinerated in a platinum crucible, and the ash obtained heated for five to eight hours with hydrochloric acid on the water bath, and finally evaporated to dryness. A fresh quantity of hydrochloric acid is added to the residue, and then water, and after heating the mixture is filtered. The

Estimation of the Phosphorus in the coke or coal

filtrate is evaporated with excess of nitric acid to convert everything present to nitrates, it is evaporated to dryness, more nitric acid and water added, and the solution is precipitated with ammonium molybdate, prepared by dissolving 30 grams of the salt in 200 c.c. of water with the addition of 200 grams of nitric acid, sp. gr. 1·2. The ammonium molybdate must always be in large excess. This liquid in the presence of small quantities of phosphoric acid turns yellow without precipitation, and to ensure the complete reaction, the solution is kept on the sand bath for at least four hours, or it may be allowed to stand in a warm place during the night. A small quantity of the liquid should be removed by a pipette, ammonium molybdate added and the liquid warmed, to ensure that all phosphorus has been precipitated. Decant the clear liquid through a small filter, disturbing the precipitate as little as possible. Wash well by decantation with a solution of 1 volume of ammonium molybdate to 4 volumes of water. Continue until the washings give no precipitate with excess of ammonia.

Treatment of the Molybdate precipitate

Precipitation of the Phosphate by Magnesia mixture

Dissolve the precipitate in the beaker with a small quantity of ammonia, and pass through filter paper, washing thoroughly. Add hydrochloric acid until the precipitate which forms only disappears slowly, then reprecipitate, in the cold, with magnesia mixture, prepared by dissolving 101 grams magnesium chloride (crystals) and 200 grams ammonium chloride in 800 c.c. of water, and adding 200 c.c. ammonia sp. grav. ·880. After standing for some time, add a fair bulk of ammonia. To ensure completion the precipitate has to stand for four to five hours. It is then filtered and thoroughly washed with dilute ammonia, prepared by mixing 1 volume of ammonia (sp. gr. 0·96) with 3 volumes of water. The washing is finished when the filtrate gives no precipitate with silver nitrate after making acid with nitric acid. The precipitate is

dried and gently heated in a platinum or porcelain crucible, after having burnt the filter paper. The cover of the crucible is put on and the heating continued slowly and gently. When the decomposition is finished the precipitate is strongly heated, first without and then with the cover on. The magnesium ammonium phosphate is changed into magnesium pyrophosphate with evolution of ammonia and water. Should the precipitate after ignition be dark in colour, just moisten with strong nitric acid, drive off the acid, and again ignite.

Calculation of the results

$$Mg_2P_2O_7 : 2P$$
$$222 : 62 = Mg_2P_2O_7 \text{ found } : x$$
$$x = 0{\cdot}2793 \times Mg_2P_2O_7 \text{ grs. phosphorus}$$
$$P = \text{quantity of coke}$$
$$P : 0{\cdot}2793 \times Mg_2P_2O_7 \text{ found} = 100 : x$$
$$x = \frac{27{\cdot}93 \times Mg_2P_2O_7 \text{ found}}{P} = \text{per cent. phosphorus.}$$

Example—

$$\text{Quantity of coke taken} = 12{\cdot}557 \text{ gr.}$$
$$Mg_2P_2O_7 \text{ found} = 0{\cdot}024 \text{ gr.}$$
$$x = \frac{27.93 \times 0{\cdot}024}{12{\cdot}557} = 0{\cdot}053 \text{ per cent. phosphorus.}$$

Analysis of the Ash.

Estimation of Silica in the ash

Estimation of Silica.—About 1 gram of the ash is heated on the water bath with strong hydrochloric acid and evaporated nearly to dryness. This is repeated three times. The residue is dissolved in hydrochloric acid, some water added, and filtered. The precipitate is well washed with boiling water, and ignited on the platinum crucible and weighed.

$$P = \text{quantity of ash}$$
$$P : SiO_2 \text{ found} = 100 : x$$
$$x = \frac{100 \times SiO_2 \text{ found}}{P}$$

Example—

$$\text{Amount of ash} = 1{\cdot}2236$$
$$SiO_2 \text{ found} = 0{\cdot}5926$$
$$x = \frac{59{\cdot}26}{1{\cdot}2236} = 48{\cdot}43 \text{ per cent. } SiO_2$$

Estimation of Iron and Alumina in the ash

Determination of iron and alumina.—The filtrate from the silicic acid is precipitated with ammonia, dissolved in hydrochloric acid, and reprecipitated. The precipitate contains iron hydroxide, aluminium hydroxide, and phosphoric acid, united with iron or alumina. The precipitate is filtered and well washed with boiling water, the filtrate being reserved for the estimation of magnesium. The precipitate is placed with the paper in a platinum crucible, dried, incinerated, ignited, and weighed. The weight represents the sum of the oxides of iron and alumina and the phosphates. The weight of phosphorus being known in the coke may be calculated as P_2O_5 in the ash.

Determination of Iron by titration

The iron is determined by titration. The precipitate is dissolved in hydrochloric acid, and the solution of ferric and aluminium chloride filtered. The filter generally retains a small amount of silicic acid, which is well washed, dried, ignited, and weighed, the weight being added to the amount previously obtained. The filtrate is made up to 100 c.c. by dilution, and a definite quantity of it, say 20 c.c., is taken in a flask, a piece of pure zinc is added, and meanwhile a current of carbon dioxide is passed through in order to prevent the action of atmospheric oxygen on the solution. The nascent hydrogen reduces the iron to ferrous chloride; a few grams of manganous sulphate are added to prevent the action of the permanganic acid on the hydrochloric acid when titrating with potassium permanganate. The permanganate solution contains 0·00316 gram of potassium permanganate to 1 c.c., and 1 c.c. of this corresponds to 0·0056 gram of iron. The permanganate solution is added to the iron solution from a burette till pink. The amount of iron, when a = the number of c.c. of permanganate solution, $0·0056 \times a$. As 20 c.c. or a fifth were taken, the total amount of iron will be—

$$0{\cdot}0056 \times a \times 5 = 0{\cdot}028a$$
or the total amount of $Fe_2O_3 = 0{\cdot}028a \times 1{\cdot}4286$.

Calculation of the results

The weight of the precipitate of iron oxide, aluminium oxide, and phosphates = R; the weight of the phosphorus calculated on P_2O_5 = A.

$$R = A + 0{\cdot}028\,a \times 1{\cdot}4286 + X$$
$$X = R - A - 0{\cdot}028\,a \times 1{\cdot}4286 = \text{gr. } Al_2O_3.$$

Example.—It was found that the ash gave 0·024 gram $Mg_2P_2O_7$, and this multiplied by 0·6396 = the quantity of $P_2O_5 = 0{\cdot}024 \times 0{\cdot}63756 = 0{\cdot}0153$ gram P_2O_5 = A.

Example of method of calculation

The quantity of Fe_2O_3 was found. $a = 3{\cdot}77$ c.c.
$$Fe_2O_3 = 0{\cdot}028 \times 3{\cdot}77 \times 1{\cdot}4286 = 0{\cdot}1509\ Fe_2O_3$$
$$R = 0{\cdot}3076$$
$$X = 0{\cdot}3076 - 0{\cdot}0153 - 0{\cdot}1509$$
$$X = Al_2O_3 = 0{\cdot}1414$$

The quantity of ash was 1·2236.

$$1{\cdot}2236 : 0{\cdot}1509 = 100 : x.\ x = \%\ Fe_2O_3 = 12{\cdot}33.$$
$$1{\cdot}2236 : 0{\cdot}1414 = 100 : x.\ x = \%\ Al_2O_3 = 11{\cdot}56.$$

Estimation of Manganese in the ash

Manganese.—If this is present, estimate the silica, iron and aluminium oxides, etc., as above, then take a fresh portion of the ash, treat as before to remove silica, nearly neutralise the solution with sodium carbonate, add excess of sodium acetate, or ammonium acetate, and boil for a short time. The iron and alumina will precipitate as basic acetates; filter off, and to the solution add bromine water and then ammonia, heat for a short time, filter, and wash. Ignite the precipitate strongly with free access of air, and weigh. The precipitate, after strongly heating, is Mn_3O_4.

Estimation of Lime

Calcium Oxide.—The filtrate from the iron and alumina, or from the manganese if present, is raised to nearly the boiling point, and excess of hot ammonium oxalate added. Boil for a short time, and allow to stand for some hours. Filter and thoroughly

wash with hot water. Heat the precipitate over the bunsen flame for some minutes, and finally over the blowpipe till the weight is constant. Weigh as CaO.

The quantity of lime present is obviously of no consequence to the carbide maker, but as it must always be removed before estimating the magnesia, it is little trouble to make the estimation.

$$\frac{\text{CaO found} \times 100}{\text{Weight of ash}} = \text{Calcium oxide per cent. in ash.}$$

Estimation of Magnesia

Magnesia.—Evaporate the filtrate from the lime estimation nearly to dryness, moisten with hydrochloric acid, and then take to complete dryness. Ignite in a platinum dish, in small quantities at a time, to drive off any large quantity of ammonium chloride, and also to render any silica, which frequently dissolves from the glass in the alkaline solutions, insoluble. Moisten the residue with hydrochloric acid, add hot water and run through a small filter. Add ammonia till alkaline, and then sodium phosphate. Ammonium magnesium phosphate is obtained. Treat as in the estimation of phosphorus.

Calculation of the result

$$Mg_2P_2O_7 : 2MgO$$
$$222 : 80 = Mg_2P_2O_7 \text{ found} : X$$
$$X = 0{\cdot}3604 \times Mg_2P_2O_7 \text{ found}$$
$$P : 0{\cdot}3604 \times Mg_2P_2O_7 \text{ found} = 100 : X$$
$$X = \text{per cent. MgO in the ash } \frac{36{\cdot}04 \times Mg_2P_2O_7 \text{ found.}}{P}$$

Example—

$$\text{Weight of ash used} = 0{\cdot}8256 \text{ gr.}$$
$$Mg_2P_2O_7 \text{ found} = 0{\cdot}0078 \text{ gr.}$$
$$\frac{36{\cdot}04 \times {\cdot}0078}{0{\cdot}8256} = 0{\cdot}34 = \text{per cent. of MgO.}$$

Analysis of the Lime or Limestone.

Analysis of the Lime or Limestone used in Carbide making

The most important estimations are phosphorus, sulphur, and magnesia, and, to a smaller extent, alumina, since these are the substances concerned in the production of phosphorus compounds, sulphur

compounds, and ammonia in the gas generated from the carbide.

In preparing the lime for analysis, every care must be taken that it is exposed to the air for the shortest possible time, owing to the avidity with which water and carbon dioxide are absorbed. Small quantities must therefore be pounded at a time, and then quickly transferred to a dry, well-stoppered bottle. The portion for analysis should be sieved through the same sized gauze as used for coke.

Loss on ignition

Loss on ignition.—Consists of moisture and carbon dioxide.

The amount for analysis and for this estimation should be weighed out at the same time. About one gram of limestone, or 0·5 gram of lime, should be weighed into a tared platinum crucible from the weighing bottle. The crucible is then heated over the bunsen flame, and finally by the blowpipe till the weight is constant.

$$\frac{\text{Loss in weight} \times 100}{\text{Weight of sample}} = \text{Loss on ignition per cent.}$$

General Analysis.

Estimation of the Silica

Silica.—Weigh about 2·5 grams of lime or 5 grams of limestone from the weighing bottle into a fair-sized porcelain dish, nearly cover with a clock glass, and add water. After a short time in the case of lime, or immediately with limestone, add a quantity of strong hydrochloric acid. When the action ceases, wash any drops of liquid that may have "spurted" on to the clock glass into the dish, and evaporate to dryness on the water bath.

Transfer the dish to a metal vessel which serves as an air bath, and heat until no moisture is deposited on a cool clock glass when placed over the dish. It is better to heat in this way than directly by the flame, and a convenient air bath can be arranged by sus-

pending the dish with a wire support inside a hemispherical metal bath, so that the sides of the bath are practically equidistant from the sides of the dish.

Moisten the residue with strong hydrochloric acid, add hot water, filter and wash thoroughly, allowing the filtrate and washings to run into a 250 c.c. flask. Dry the filter, ignite, and weigh as usual.

$$\frac{\text{Weight of } SiO_2 \times 100}{\text{Weight of sample}} = \text{per cent. } SiO_2.$$

Example—

Weight of lime used = 2·3216
SiO_2 found = 0·0241

$$\frac{0{\cdot}0241 \times 100}{2{\cdot}3216} = 1{\cdot}03 \text{ per cent. } SiO_2.$$

Estimation of Iron and Alumina

Iron and Alumina.—Cool the contents of the 250 c.c. flask, and make up the volume to 250 c.c. Pipette off 50 c.c. for the analysis. Add ammonium chloride and ammonia in excess to the hot solution. Allow the precipitate to subside, and wash twice by decantation. Set aside the filtrate and washings. Dissolve the precipitate in a little warm hydrochloric acid, one part acid to one part water, and precipitate again by ammonia. Wash by decantation and, finally, wash on filter till washings give no precipitate with silver nitrate.

Dry the precipitate and heat to low redness in a platinum crucible.

$$\frac{\text{Weight of ppt.} \times 100 \times 5}{\text{Weight of sample}} = \text{per cent. of iron and aluminium oxides.}$$

Example—

50 c.c. of solution used. 250 c.c. contained 2·3216 grams.
Weight of iron and aluminium oxides found = 0·0025 gr.

$$\frac{0{\cdot}0025 \times 100 \times 5}{2{\cdot}3216} = 0{\cdot}53 \text{ per cent. of iron and aluminium oxides.}$$

If much phosphate be present the same method may be employed as with the iron and alumina in coke ash.

Lime and Magnesia.—Proceed exactly as for analysis of coke ash. For very accurate analysis, it is necessary to redissolve the calcium oxalate precipitate and reprecipitate the lime, but with small quantities of magnesium this is seldom required. It must be remembered in calculating the results that only one-fifth of the sample is being used in the analysis.

Estimation of Lime and Magnesia

$$\frac{\text{CaO found} \times 100 \times 5}{\text{Weight of sample}} = \text{CaO per cent.}$$

Calculation for the Lime and Magnesia

Example—

CaO. 50 c.c. of solution used.

$$\text{CaO found} = 0{\cdot}4391 \text{ gr.}$$

$$\frac{0{\cdot}4391 \times 100 \times 5}{2{\cdot}3216} = 94{\cdot}56 \text{ per cent. of CaO.}$$

MgO. 50 c.c. of solution used.

$$Mg_2P_2O_7 \text{ found} = 0{\cdot}0152 \text{ gr.}$$

$$\frac{0{\cdot}0152 \times 0{\cdot}3604^* \times 100 \times 5}{2{\cdot}3216} = 1{\cdot}18 \text{ per cent. of MgO.}$$

$Mg_2P_2O_7 = 2\ P$

$222 \qquad 62$ or $\dfrac{2\ P}{Mg_2P_2O_7} = 0{\cdot}3604.$

Sulphur.—Heat 100 c.c. of the solution to boiling, and add a boiling solution of barium chloride. Continue boiling for half an hour. Allow any precipitate to settle, decant liquid, and thoroughly wash the precipitate till the washings are free from chlorides. Dry, ignite, and weigh as $BaSO_4$.

Estimation of the Sulphur in Lime

Since 250 c.c. are from the weight of lime taken, the weight of $BaSO_4$ from 100 c.c. must be multiplied by 2·5.

$BaSO_4 = SO_3$

$233 \ = 80 \qquad \dfrac{SO_3}{BaSO_4} = 0{\cdot}3434.$

$$\frac{BaSO_4 \text{ found} \times 0{\cdot}3434 \times 100 \times 2{\cdot}5}{\text{Weight of sample}} = \text{per cent. } SO_3.$$

Example—

100 c.c. solution used.

$$BaSO_4 \text{ found} = 0{\cdot}0348 \text{ gr.}$$

$$\frac{0{\cdot}0348 \times 0{\cdot}3434 \times 100 \times 2{\cdot}5}{2{\cdot}3216} = 0{\cdot}128 \text{ per cent. } SO_3.$$

Estimation of the Phosphates in the Lime

Phosphorus.—About 12 to 15 grams of the lime or limestone should be taken and treated for the removal of silica as above. With this large amount it is necessary to carefully break up lumps with a rod during the drying by hot air. Filter off the silica and evaporate the filtrate with strong nitric acid until nearly dry, to remove the hydrochloric acid and convert everything into nitrates. Dilute and precipitate with ammonium molybdate as in the coke analysis, afterwards estimating as magnesium pyrophosphate.

$$Mg_2P_2O_7 = P_2O_5$$
$$222 = 142 \quad \text{or} \quad \frac{P_2O_5}{Mg_2P_2O_7} = 0{\cdot}6396.$$

Calculation of the result

$$\frac{Mg_2P_2O_7 \text{ found} \times 0{\cdot}6396 \times 100}{\text{Weight of sample}} = \text{per cent. } P_2O_5.$$

Example—

$$\text{Weight of lime taken} = 9{\cdot}6990 \text{ gr.}$$
$$Mg_2P_2O_7 \text{ found} = 0{\cdot}0068 \text{ gr.}$$
$$\frac{0{\cdot}0068 \times 0{\cdot}6396 \times 100}{9{\cdot}6990} = 0{\cdot}048 \text{ per cent. of } P_2O_5.$$

Analysis of Calcium Carbide.

The estimation of the gas-yielding power of Calcium Carbide

Many processes have been devised for the estimation of the yield of acetylene from a given sample of carbide. Theoretically, pure carbide should give 348·9 litres of acetylene per kilo at 0° C. and 760 mm., corresponding to 5·8 cubic feet per pound; but even if the carbide were absolutely pure, these figures would never be practically reached owing to the fact that it is impossible to prevent some carbide, even though the amount be small, being decomposed by the water vapour in the atmosphere before the carbide is put into the generator. The commercial carbide is often packed in big lumps, which have to be broken before being used, and during this operation there is always a certain amount of decomposition.

Loss due to moisture in the air

Breaking the carbide to a certain size is absolutely

necessary in order to get a good average sample for analysis. The finer the carbide is broken the greater will be the loss of acetylene set free on generation, due to two causes: (*a*) the longer time required for breaking, and (*b*) the greater surface exposed to the action of the damp air.

The effect of breaking on the yield of calcium carbide was found by Perrodil[1] to be per 1 kgr.:—

Effect of breaking down Carbide on the yield of gas

Lumps as received from the works .	310 litres
Granulated	290 „
Powdered	200 „

The quantity of acetylene evolved from a given weight also depends partly on the apparatus used. In dripping generators there will be a certain loss owing to polymerisation, due to the rising temperature. In generators where the carbide is allowed to drop into water, a certain amount of gas will be dissolved by the water. This error may to a certain extent be obviated by using lime water saturated with acetylene for the decomposition, and if the decomposition takes place in a relatively large volume of saturated lime water, and is effected very slowly, then the figures obtained may approximate closely to theory, because the temperature does not rise much. If the temperature rises even 10 to 20° C., the volume of acetylene obtained may be greater than the amount generated from the carbide, owing to some being driven out of solution in the water.

Loss due to heating in the generator

The influence of the generators on the yield was tested, the figures obtained being:—

Influence of mode of generation on the volume of the gas

1. Test of yield by weighing dripping apparatus, slowly dripping brine—

1 kgr. carbide = 307·5 : 306·4 : 307·1 litres.

2. Carbide into lime water saturated with acetylene by

[1] *Rev. Tech. Acet.* 2, 182.

measuring the volume. 60 gr. of carbide in 500 c.c. of saturated lime water—

1 kgr. carbide = 310·6 l. : 306 l. : 308 l.

3. Dripping apparatus by measuring the volume, quickly running the water in, so that a great increase in temperature takes place, and products of polymerisation are formed—

1 kgr. carbide = 295 l. : 279 l. : 283 l.

These figures show that the two first methods give nearly the same results, when in the dripping apparatus brine is used and the temperature does not rise high enough to form polymerisation products. When using water, however, and working quickly, the yield is much less.

Influence of the crystalline character of the Carbide on heating during generation

The character of the carbide also affects this to a considerable extent, a pure ingot carbide in large crystals decomposing more quickly and evolving higher temperatures than the dense grey carbide.

Sampling the carbide.—On examination, carbide will usually be found to vary considerably in appearance, and in taking the sample great attention must be paid to obtaining a fair average. Further, it is often then very difficult to get a result which is even fairly accurate if only sufficient is broken up for the test. At least 250 grams should be reduced to about the size of hazel nuts and well mixed, and from the bulk the required quantity for the estimation is taken.

The importance of proper sampling in taking specimens for analysis

The following case illustrates the importance of these precautions.

(*a*) Sample of carbide obtained by choosing apparently representative pieces, breaking only sufficient for analysis.

(*b*) The same carbide, only a large quantity broken, and then the sample taken from the reduced mass.

	Carbide taken.	Gas yield per kilo.	Calculated percentage of pure carbide.
(*a*)	49·82 gr.	179 litres	51·34
(*b*)	55·44 „	271 „	77·80

The first method proposed for the estimation of the

yield of gas from calcium carbide is due to Perrodil and Sertier,[1] who devised an apparatus which, although useless for accurate scientific tests, can be used in many cases to obtain a rough estimation for the volume of gas obtainable from a given sample. It consists of an ordinary drip generator, from which the gas generated from a known quantity of calcium carbide is led through a tube containing cotton wool to retain dust, condensed water vapour, polymerisation products, etc., and is then led into a graduated holder. Perrodil claims that with this apparatus it is possible to test, not only the volume of acetylene generated from a given sample of carbide, but also the residue left after decomposition and the photometric value of the gas.

Method proposed by Perrodil and Sertier

In the apparatus used by him, the height of the gas-holder bell was 30 cm., and with a holder of this size, the error in reading the volume may amount to roughly one-thirtieth of a volume; so that with a commercial carbide yielding 300 litres per kilo, an error of 10 litres might occur, whilst this is added to by any errors in the weighing out of the carbide.

Possible error of the process

In estimations of this kind corrections for the temperature of the gas in the holder and for the pressure should be employed, and the process could only be used for rough estimations.

In 1897 Lunge and Cederkreutz [2] made an apparatus in which a generator of the kind shown in Fig. 12, p. 60, is employed in which carbide is allowed to drop into water, or a dripping apparatus can be used, and the gas evolved is measured in a graduated holder. In the first case the test can be made in a very short time. The generator is filled with brine, the carbide is weighed, placed in the receiver, which is connected by a rubber tube to the decomposing

Method adopted by Lunge and Cederkreutz

[1] *Rev. Tech. Acet.* 2, 181; *Zeitsch. f. Calc. und Acet.* 1, 163.
[2] *Zeitsch. f. Anorg. Chem.*, 1897, 654.

flask; in order to prevent the carbide dropping in too large quantities into the generating flask, the rubber tube should be fitted with a suitable pinch cock. When the acetylene is collected over brine, the vapour tension may be disregarded for commercial purposes.

With this apparatus greater quantities of carbide can be tested at once, say 50 grams. When the water is added drop by drop, the generation may be stopped when the holder is full and the gas burnt, when the reaction may be started afresh.

Advantage of the process

In this way the error is diminished. Instead of an error of 10 litres, it is reduced to $\frac{10}{5}$, so that it is possible to reduce the error on 1 kgr. to 2 litres.

Atmospheric temperature and pressure should be corrected for, and also for the temperature of the gas where a drip generator is used; and it must also be borne in mind that during the burning off of the acetylene, the evolution of gas does not cease entirely. This method, however, is of practical use in many cases for rough estimations.

Process employed by Fuchs and Schiff for the estimation of the yield of gas

In 1897 Fuchs and Schiff[1] pointed out the difficulties of collecting acetylene over water, and recommended covering the water in the collecting holder with a layer of olive oil in order to separate it from the former. Their observations show that 100 volumes of olive oil absorb 48 volumes of acetylene, whilst water absorbs its own volume. For testing the yield of acetylene set free from calcium carbide, they use the following method:—

A three-necked Woulffe's bottle is fitted with corks carrying a thermometer, dripping funnel, and outlet tube respectively, and the bottom of the bottle is covered with asbestos to prevent its cracking from any sudden rise of temperature. A gas jar of 15 litres capacity is filled with water covered by a layer of olive oil, and is closed by a cork fitted with a syphon

[1] *Chem. Zeit.* 21, 875.

leading to a second measuring receiver, and a tube with stopcock leading to the outlet of the Woulffe's bottle. The syphon having been filled with water by blowing down the inlet tube, the stopcock is closed and the generating bottle connected on. 30 to 40 grams of carbide are weighed by difference in a closed tube, and are thrown into the bottle. The initial temperature is then noted, and the dripping funnel is filled with 200 c.c. of water, and the tap opened so that the water drops very slowly on to the carbide, whilst at the same time the stopcock in the connecting tube is opened. As the gas passes into the gas jar, the water is displaced and passes through the syphon into the measuring vessel, and from the volume so obtained the yield of acetylene can be calculated. It is claimed that when properly used, the apparatus gives very concordant results.

Apparatus employed

Five tests of two samples of carbide from Neuhausen gave the following figures:—

Results obtained

1 kgr.	281·3		290·5	
	285·6	mean	295·1	mean
	287·2	286·8 litres.	298·6	297·6 litres.
	289·5		299·8	
	290·3		303·9	

So far the methods employed were all dependent upon measuring directly the volume of acetylene set free from a definite quantity of carbide, and it is manifest that this is open to many objections. It was Bamberger, in 1898,[1] who first proposed to determine the yield of acetylene gravimetrically, a process which is not only more accurate than the previous ones, but also more simple and easy in working.

In order to do this he employed the apparatus shown in Fig. 226, which consists of a two-necked Woulffe's bottle fitted with a calcium chloride tube

Bamberger's method of estimating the yield of gas gravimetrically

[1] *Zeit. f. Calc. und Acet.* 1, 210.

and a dripping funnel, which, before the experiment, is filled with a solution of salt. The weight of the bottle thus fitted is first taken, and then about 50 to 60 grams of the calcium carbide which is to be tested are put in the bottle and the weight once more taken, the increase in weight giving the amount of carbide added. For weighing this apparatus a balance turning with 0·01 gram with 800 grams may be used, the final results being very accurate. The weighed apparatus is ready for the analysis.

Method of conducting the estimation

FIG. 226. BAMBERGER'S APPARATUS.

The tap is opened so that five to six drops fall per minute; the carbide is decomposed slowly, and the gas set free is dried by the calcium chloride. Later on the brine may be allowed to drip more quickly. With careful working, only the lower part of the generator will be heated, and not a trace of water vapour escapes. After three to four hours half of the brine taken has passed in, and the carbide is nearly all decomposed. The tap is opened, and the remainder of the brine allowed to flow in. The bottle is shaken, and air aspirated through the generator for displacement of acetylene by air. When the apparatus has acquired its original temperature it is weighed, the difference in weight giving the weight of acetylene set free. By a simple calculation, the amount of pure carbide

and the yield of acetylene per kgr. are obtained. One kgr. of pure carbide evolves 40·625 per cent. of acetylene, or the yield for 1 kgr. is 348·9 litres at 0° C. and 760 mm.

The error due to weighing the apparatus in the first place full of air and afterwards full of acetylene, would probably not be greater than the experimental error combined with error in sampling the carbide. Thus if the apparatus have a capacity of 1 litre—it will probably be less—

Probable extent of error involved

1 litre of air	=1·293 gr.
1 litre of acetylene	=1·168 gr.
	0·125 gr. difference.

Assuming a carbide yields 300 litres per kilo, the 50 grams yield 17·520 grams acetylene. This would be reduced by 0·125 if the apparatus were weighed full of acetylene after the determination, or 17·520 − 0·125 = 17·395 grams acetylene.

17·395 grams acetylene would then give the yield per kilo as 297·58 litres, or an error of 2·42 litres per kilo.

The calculation of the yield of acetylene and the percentage of pure carbide may be made as follows:—

Calculation of yield of gas and percentage of Carbide from results obtained

Apparatus + carbide	624·89
Apparatus	575·99
Weight of carbide	48·90
Weight of apparatus after experiment .	607·38
	624·89
	607·38
Weight of acetylene .	17·51

$$48{\cdot}90 : 17{\cdot}51 = 100 : x$$

$$x = \frac{17{\cdot}51}{48{\cdot}9} = 35{\cdot}8 \text{ per cent. of acetylene.}$$

35·8 per cent. of acetylene = 88 per cent. pure carbide, and this corresponds to

1 kgr. = 307 litres.

The time needed for such a test depends on the quantity of carbide used.

Ratio between volume of gas yielded and percentage of true Carbide

The following table shows the relation between the volume of gas yielded by calcium carbide in litres per kilo and the percentage of true calcium carbide contained in the commercial material, the volume being calculated at 0° C. and 760 mm. barometric pressure.

Per cent. of pure carbide	Litres per kgr.	Difference.	Percentage of acetylene.	Difference.
100	348·9	3·5	40·625	0·40
99	345·4	3·5	40·22	0·41
98	341·9	3·5	39·81	0·41
97	338·4	3·5	39·40	0·40
96	334·9	3·4	39·00	0·41
95	331·5	3·5	38·59	0·40
94	328·0	3·5	38·19	0·41
93	324·5	3·5	37·78	0·41
92	321·0	3·5	37·37	0·40
91	317·5	3·5	36·97	0·41
90	314·0	3·5	36·56	0·41
89	310·5	3·5	36·15	0·41
88	307·0	3·5	35·74	0·41
87	303·5	3·5	35·33	0·41
86	300·0	3·5	34·92	0·40
85	296·5	3·5	34·52	0·41
84	293·0	3·5	34·11	0·41
83	289·5	3·5	33·70	0·41
82	286·0	3·5	33·29	0 41
81	282·5	3·5	32·88	0·41
80	279·0	3·5	32·47	0·41
79	275·5	3·5	32·06	0·41
78	272·0	3·5	31·65	0·41
77	268·5	3·5	31·24	0·41
76	265·0	3·5	30·83	0·41
75	261·5	3·5	30·42	0·41
74	258·0	3·5	30·01	0·41
73	254·5	3·5	29·60	0·41
72	251·0	3·5	29·19	0·41
71	247·5	3·5	28·37	0·41
70	244·0	3·5	28 37	0·41

If the yield in litres per kilo be divided by 63, it gives approximately the result in cubic feet per pound.

Bamberger's apparatus may also be connected directly to a measuring cylinder or gasholder, Fig. 227, so that the results obtained by weight may be checked by direct measurement.

Direct check on the gravimetric result by measuring volume of gas

As shown in Chapter IX., acetylene, when made from calcium carbide, nearly always contains traces of phosphuretted and sulphuretted hydrogen, together with small quantities of ammonia and air, the latter

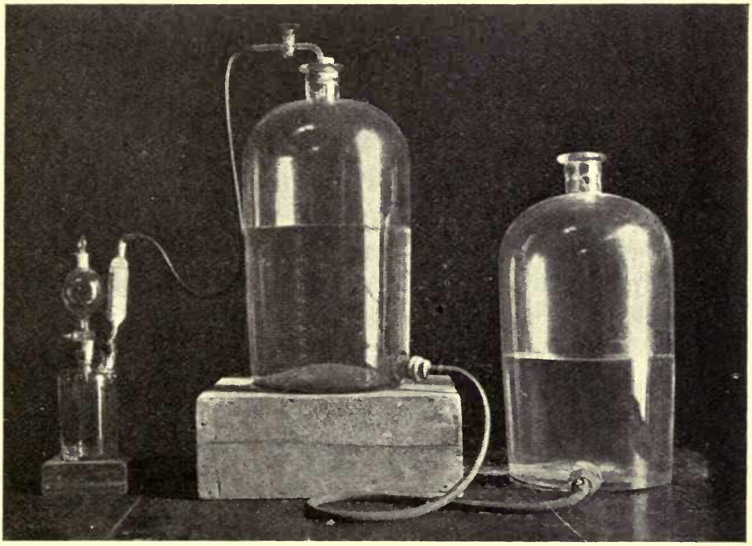


Fig. 227.

being accidently introduced in generation or collection of the sample of gas for analysis.

Qualitative tests for the impurities in Acetylene

Qualitatively the presence of sulphuretted hydrogen in crude acetylene is readily demonstrated by passing the gas through a solution of lead acetate, when a black precipitate of lead sulphide soon forms; whilst if, after freeing the gas from sulphuretted hydrogen in this way, it is then passed through a solution of silver nitrate, the presence of phosphuretted hydrogen is shown by the formation of a yellow precipitate of

double phosphide and nitrate of silver, which turns black owing to its decomposition into silver phosphide. This reaction is very sensitive, but even more delicate is the test devised by Berge and Reyschler,[1] who use a solution of mercuric chloride in hydrochloric acid, which gives a white amorphous precipitate on contact with phosphuretted hydrogen.

The presence of ammonia can readily be shown by passing the acetylene through a dilute solution of red litmus, which is rapidly turned blue.

Quantitative Methods for the Estimation of Phosphuretted Hydrogen.

Estimation by means of Bromine water

The first method used for the quantitative determination of phosphuretted hydrogen was its oxidation by means of bromine water into phosphoric acid.[2] The phosphuretted, and, at the same time, the sulphuretted, hydrogen, are decomposed and oxidised to phosphoric and sulphuric acid. This reagent not only acts upon these impurities, but also on acetylene itself, so that a large amount of bromine is necessary, the fumes evolved being a decided drawback to the process.

The apparatus needed for this test consists of a dripping generator and an absorption vessel for the action of bromine on the acetylene set free. When the action is finished, the bromine water is poured into a beaker, and the absorption vessel well washed with water to remove all traces of the bromine, the wash water being added to the original liquid. The solution is gently heated in order to volatilise the excess of bromine, and ammonia is added in slight excess. The phosphoric acid having been transformed by the ammonia into ammonium phosphate, $(NH_4)_3PO_4$,

[1] *Bull. Soc. Chem.* 3, 7, 218.
[2] Willgerodt, *Berl. Ber.* 29, 2,107 (1895).

is precipitated by the magnesia mixture as ammonium magnesium phosphate.

Precipitation of the Phosphate

$$(NH_4)_3PO_4 + MgCl_2 = MgNH_4PO_4 + 2\ NH_4Cl$$

The precipitation is effected at ordinary temperature, and the washing is carried out as directed under the estimation of phosphorus in coke, the precipitate in each case being ammonium magnesium phosphate.

The magnesia mixture is prepared by dissolving 101 grams of crystallised magnesium chloride, 200 grams of ammonium chloride in 800 c.c. of water, and adding 200 c.c. ammonia sp. grav. ·880.

Estimation of the Phosphorus Pentoxide in the products of combustion

The large amount of bromine needed for the oxidation of phosphuretted hydrogen, if the acetylene has to pass through the bromine water, may be reduced by burning the acetylene and passing the products of combustion through an absorbing solution, such as dilute ammonia, and precipitating this with the magnesia solution. This method, however, is always liable to error, as when the acetylene evolved is first collected in a holder over water or brine there is a certain amount of phosphuretted hydrogen absorbed, and this may introduce a serious error, owing to the small percentage of phosphuretted hydrogen present, and it is practically impossible to decompose the calcium carbide in a dripping apparatus and then burn the gas directly, as it is very difficult to obtain a constant flame which will not smoke.

The estimation of Phosphuretted and Sulphuretted Hydrogen by Sodium Hypochlorite

Lunge and Cererkreutz[1] proposed oxidising the phosphuretted and sulphuretted hydrogen by means of a sodium hypochlorite solution. It was known the chloride of lime oxidises phosphuretted hydrogen easily and completely, whilst solutions of hypochlorites are without any action on acetylene at ordinary temperatures. Chloride of lime is not suitable for analytical

[1] *Zeitsch. f. Anorg. Chem.*, 1897, 654.

purposes, but a solution of sodium hypochlorite answers admirably.

The apparatus used consists of a flask with dripping funnel and an absorption tube. It is preferable to combine the test for yield of gas with the analysis, as Bamberger does, and to use the latter apparatus with a series of absorption bulbs (Fig. 228).

Method of carrying out

The carbide is weighed in Bamberger's generator and connected with the absorption bulbs containing

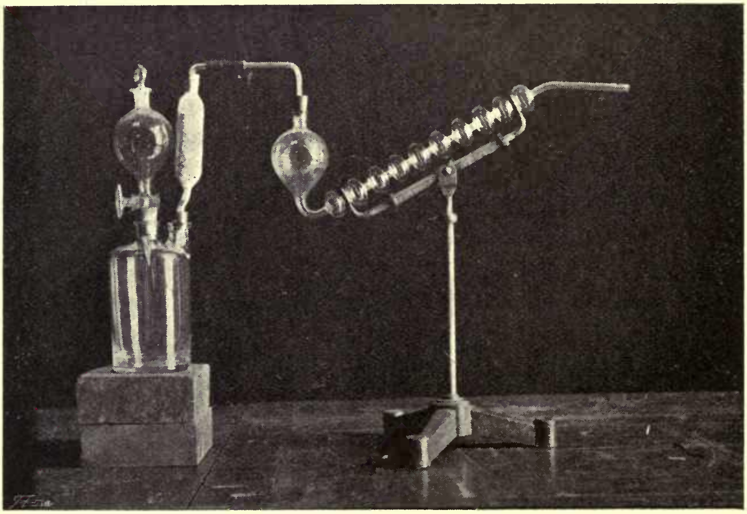


FIG. 228.

the determination at same time as estimation of yield of gas

nearly 75 c.c. of a 2 to 3 per cent. solution of sodium hypochlorite. The tap of the dripping funnel is slightly opened, and the brine drips very slowly on to the carbide. The acetylene set free passes through the calcium chloride tube to retain any water, and bubbles through the hypochlorite. When the carbide is all decomposed some air is aspirated through the apparatus, and the generator weighed again, the difference in weight giving a means of calculating the yield of acetylene. The hypochlorite solution is poured

into a beaker and the absorption tube well rinsed out with water, this wash water being added to the original. The solution contains all the phosphorus as sodium phosphate and the sulphur as sodium sulphate. The phosphate is then precipitated with magnesia mixture, and the precipitate of ammonium magnesium phosphate filtered, washed, ignited, and weighed as before. From the amount of magnesium pyrophosphate obtained the quantity of phosphuretted hydrogen can be calculated.

Precipitation of the Phosphate

According to experiments it is not necessary to destroy the hypochlorite first; the solution may be precipitated directly, but ammonium chloride should be added before the magnesia mixture, otherwise a flocculent precipitate will be produced, probably $Mg(HO)_2$.

The filtrate contains all the sulphur as sulphate of sodium, and should be collected for this determination.

The calculation of results for phosphuretted hydrogen or phosphorus in acetylene may be made as follows :—

Calculation of the results obtained

$$\text{Since}\quad Mg_2P_2O_7 : 2\,PH_3$$
$$222 : 68 = Mg_2P_2O_7 \text{ found} : x.$$
$$x = \text{gr. } PH_3 = 0{\cdot}3063 \times Mg_2P_2O_7 \text{ found in acetylene set free.}$$

$$V = \text{volume of acetylene in c.c.}$$
$$V : 0{\cdot}3063 \times Mg_2P_2O_7 \text{ found} = 1{,}000 : x.$$
$$x = \text{gr. } PH_3 \text{ in } 1{,}000 \text{ c.c.} = \frac{306{\cdot}3 \times Mg_2P_2O_7 \text{ found}}{V}.$$
$$1 \text{ gr. } PH_3 = 654{\cdot}5 \text{ c.c. at } 0^\circ \text{ C. and } 760 \text{ mm.};$$

$$\text{hence the volume of } PH_3 = 0{\cdot}3063 \times Mg_2P_2O_7 \text{ found} \times 654{\cdot}5 \text{ c.c.}$$
$$\text{or } = 200{\cdot}46 \times Mg_2P_2O_7 \text{ found c.c.}$$

V = volume of acetylene evolved in c.c.
1 gr. acetylene = 855·65 c.c.
1 litre hydrogen = 0·0899 c.c.

$$V : 200{\cdot}46 \times Mg_2P_2O_7 \text{ found} = 100 : x.$$
$$x = \text{per cent. } PH_3 = \frac{200{\cdot}46 \times Mg_2P_2O_7 \text{ found}}{V}.$$

Example—

$$\text{Volume of acetylene evolved} = 16{,}100 \text{ c.c.}$$
$$\text{Magnesium pyrophosphate } Mg_2P_2O_7 = 0{\cdot}1060 \text{ gr.}$$
$$x = \frac{200{\cdot}46 \times 0{\cdot}1060}{16{,}100} = 0{\cdot}132 \text{ per cent. } PH_3$$

This calculation is to be used for all other methods for the estimation of phosphuretted hydrogen, if finally weighed as magnesium pyrophosphate.

Owing to the fact that all the phosphorus present in the acetylene does not exist as phosphuretted hydrogen, it is better to estimate the total phosphorus as phosphorus and not as phosphuretted hydrogen, and at the present time the amount is generally given per cubic metre, so that the amended calculation will be :—

Calculation as grams per cubic metre

$$Mg_2P_2O_7 : P_2$$
$$222 : 62 = Mg_2P_2O_7 \text{ found} : x.$$
$$x = 0{\cdot}2793 \times Mg_2P_2O_7 \text{ found} = \text{gr. phosphorus.}$$
$$V = \text{volume of acetylene in litres.}$$
$$V : 0{\cdot}2793 \times Mg_2P_2O_7 \text{ found} = 1{,}000 : x.$$
$$x = \frac{2{,}793 \times Mg_2P_2O_7 \text{ found}}{V} = \text{gr. phosphorus in 1 cb. m.}$$

Volumetric Test for Phosphuretted Hydrogen.

Volumetric estimation of Phosphuretted Hydrogen

Hempel and Karl[1] have published a volumetric method which consists of taking 1 c.c. of a copper sulphate solution, prepared by dissolving 15·6 grams of crystallised copper sulphate in 100 c.c. of water and adding 5 c.c. of dilute sulphuric acid—1 vol. of acid to 4 vols. of water. The phosphuretted hydrogen is decomposed by this solution, copper phosphide is formed, and hydrogen set free.

For the estimation of the phosphuretted hydrogen, the commercial carbide is decomposed by dropping it into water, the gas collected free from sulphuretted hydrogen and ammonia in a burette over mercury, and then allowed to pass into an absorption pipette

[1] *Zeitsch. f. Calc. und Acet.* 1, 182, 190.

containing 3 c.c. of the copper sulphate solution, which has first been saturated with acetylene. After shaking for three minutes the gas is measured, and the authors say that the fourth part of the difference in volume represents the volume of phosphuretted hydrogen. It may be mentioned that the gas cannot be collected in a holder before testing, because the phosphuretted hydrogen is decomposed by light and water, and it must not stand long over mercury for the same reason.

Example—

Acetylene used, 97·5 c.c.
Difference on volume after absorption, 1·1 c.c.

$$\frac{1 \cdot 1}{4} = 0 \cdot 28 \text{ c.c. } PH_3.$$

$$97 \cdot 5 : 0 \cdot 28 = 100 : x.$$

$$x = \frac{28}{97 \cdot 5} = 0 \cdot 280 \text{ per cent. } PH_3$$

When the acetylene contains, as at present, only 0·01 to 0·06 per cent. of phosphuretted hydrogen, this method must be used very carefully, the copper solution especially must be saturated with acetylene at a given temperature or else serious errors may occur, and in many cases the results are not so reliable as when estimated by sodium hypochlorite or hypobromite.

Determination of the Sulphur compounds in Acetylene

Determination of Sulphuretted Hydrogen or Total Sulphur.—As before stated, the gas evolved by the decomposition of commercial carbide always contains a certain amount of sulphuretted hydrogen. But there are also other organic sulphur compounds in the gas which will also produce sulphur dioxide when burnt with the acetylene. Lunge and Cederkreutz [1] found that after passing the gas through lead acetate solution, though the gas was entirely free from sulphuretted hydrogen, when bubbled through sodium hypochlorite solution, sulphate of sodium was always

[1] *Zeitsch. f. Anorg. Chem.*, 1897, 654.

found, a fact also observed by Moissan and Caro. The method for the estimation of the phosphuretted hydrogen by means of sodium hypochlorite solution gives therefore a process for the estimation of the total sulphur in the commercial acetylene.

Precipitation of the Sulphur as Barium Sulphate

The filtrate from the magnesium ammonium phosphate is slightly acidulated with hydrochloric acid and heated to boiling, hot barium chloride solution being then added in slight excess, and the liquid boiled for half an hour. The precipitate of barium sulphate is allowed to settle, filtered, and well washed with boiling water. The precipitate is ignited in a porcelain crucible. If the analysis is to be very accurate, the precipitate after ignition may be again treated with hydrochloric acid, which dissolves small traces of barium chloride held by the barium sulphate, and which cannot be removed by washing with boiling water. The hydrochloric acid is diluted with water and filtered on a small filter, so that the greater part of the precipitate remains in the crucible. The filter is added to the original precipitate in the crucible, and thoroughly dried on the water bath. The filter is then burnt and the precipitate ignited for half an hour.

Calculation of results

The total sulphur is generally calculated as sulphuretted hydrogen.

$$BaSO_4 : H_2S$$

$$233 : 34 = BaSO_4 \text{ found} : x.$$

x=gr. $H_2S = 0{\cdot}1459 \times BaSO_4$ found in the acetylene set free.

V=volume of acetylene.

$$V : 0{\cdot}1459 \times BaSO_4 \text{ found} = 1{,}000 : x.$$

$$x = \text{gr. } H_2S \text{ in } 1{,}000 \text{ c.c.} = \frac{145{\cdot}9 \times BaSO_4 \text{ found}}{V}.$$

1 gr. H_2S at 0°C. and 760 mm. = 654·5. 1 litre hydrogen = 0·0899 gr.

Hence the volume of $H_2S = 0{\cdot}1459 \times BaSO_4$ found $\times$ 654·5.

$= 95{\cdot}49 \times BaSO_4$ found.

$$V : 95{\cdot}49 \times BaSO_4 \text{ found} = 100 : x.$$

$$x = \text{vol. per cent. of } H_2S = \frac{9{,}549 \times BaSO_4 \text{ found}}{V}.$$

Example—

$$V = \text{acetylene evolved} = 18{,}400 \text{ c.c.}$$
$$BaSO_4 \text{ found} = 0{\cdot}1348 \text{ gr.}$$
$$x = \frac{9{,}549 \times 0{\cdot}1348}{18{,}400} = 0{\cdot}07 \text{ vol. per cent. } H_2S.$$

It is better however to calculate the sulphur as sulphur and not as sulphuretted hydrogen, as it does not all exist as sulphuretted hydrogen in the gas, and it is now the general practice to express the results in cubic metres instead of per cent.

Calculation as grams of Sulphur per cubic metre

$$BaSO_4 : S$$
$$233 : 32 = BaSO_4 \text{ found} : x.$$
$$x = \text{gr. sulphur} = 0{\cdot}1373 \times BaSO_4 \text{ found.}$$
$$V = \text{volume of acetylene in litres.}$$
$$V : 0{\cdot}1373 \times BaSO_4 \text{ found} = 1{,}000 : x.$$
$$x = \text{gr. sulphur in cb. m.} = \frac{137{\cdot}3 \times BaSO_4 \text{ found}}{V}.$$

(See Tables on pages 690, 691.)

Estimation of Ammonia.

The estimation of ammonia is done by titration by means of decinormal solution of sulphuric acid. For this purpose two solutions are prepared, one containing—

Estimation of Ammonia

4·9 grams sulphuric acid in 1 litre, or 0·0049 gram in 1 c.c.;

the other one containing—

1·7 grams of ammonia in 1 litre, or 0·0017 gram in 1 c.c.

1 c.c. of the first solution exactly neutralises 1 c.c. of the second.

The acetylene set free is allowed to bubble through a definite quantity of this decinormal sulphuric acid, 50 c.c. being introduced with a pipette into an absorption tube as used for the phosphuretted hydrogen test. When the whole of the acetylene has passed, all the ammonia has been absorbed and changed into sulphate or hydrosulphate of ammonia. This solution is

Table for the con-version of percentage results into grams per cubic metre

TABLE FOR THE CONVERSION OF VOLUME PER CENT. INTO GRAMS OF PHOSPHORUS OR SULPHUR PER CUBIC METRE (POLIS).

Volume per cent. of Phosphuretted Hydrogen or Sulphuretted Hydrogen. =	gr. Phosphorus per 1 cb. m. =	gr. Sulphur per 1 cb. m.
0·010	0·140	0·145
0·011	0·154	0·1595
0·012	0·168	0·1740
0·013	0·182	0·1885
0·014	0·196	0·2030
0·015	0·210	0·2175
0·016	0·224	0·2320
0·017	0·238	0·2465
0·018	0·252	0·2610
0·019	0·266	0·2755
0·020	0·280	0·2900
0·021	0·294	0·3045
0·022	0·308	0·3190
0·023	0·322	0·3335
0·024	0·336	0·3480
0·025	0·350	0·3625
0·026	0·364	0·3770
0·027	0·378	0·3915
0·028	0·392	0·4060
0·029	0·406	0·4205
0·030	0·420	0·4350
0·031	0·434	0·4495
0·032	0·448	0·4640
0·033	0·462	0·4785
0·034	0·476	0·4930
0·035	0·490	0·5075
0·036	0·504	0·5220
0·037	0·518	0·5365
0·038	0·532	0·5510
0·039	0·546	0·5655
0·040	0·560	0·5800
0·041	0·574	0·5954
0·042	0·588	0·6090
0·043	0·602	0·6235
0·044	0·616	0·6380
0·045	0·630	0·6525
0·046	0·644	0·6670
0·047	0·658	0·6815
0·048	0·672	0·6960
0·049	0·686	0·7105
0·050	0·700	0·7250
0·051	0·714	0·7395
0·052	0·728	0·7540

Volume per cent. of Phosphuretted Hydrogen or Sulphuretted Hydrogen. =	gr. Phosphorus per 1 cb. m. =	gr. Sulphur per 1 cb. m.
0·053	0·742	0·7685
0·054	0·756	0·7830
0·055	0·770	0·7975
0·056	0·784	0·8120
0·057	0·798	0·8265
0·058	0·812	0·8410
0·059	0·826	0·8555
0·060	0·840	0·8700
0·061	0·854	0·8845
0·062	0·868	0·8990
0·063	0·882	0·9135
0·064	0·896	0·9280
0·065	0·910	0·9425
0·066	0·924	0·9570
0·067	0·938	0·9715
0·068	0·952	0·9860
0·069	0·966	1 0005
0·070	0·980	1·0150
0·071	0·994	1·0295
0·072	1·008	1·0440
0·073	1·022	1·0585
0·074	1·036	1·0730
0·075	1·050	1·0875
0·076	1·064	1·1020
0·077	1·078	1·1165
0·078	1·092	1·1310
0·079	1·106	1·1455
0·080	1·120	1·1600
0·081	1·134	1·1745
0·082	1·148	1·1890
0·083	1·162	1·2035
0·084	1·176	1·2180
0·085	1·190	1·2325
0·086	1·204	1·2470
0·087	1·218	1·2615
0·088	1·232	1·2760
0·089	1·246	1·2905
0·090	1·260	1·3050
0·091	1·274	1·3195
0·092	1·288	1·3340
0·093	1·302	1·3485
0·094	1·316	1·3630
0·095	1·330	1·3775
0·096	1·344	1·3920
0·097	1·358	1·4065
0·098	1·372	1·4210
0·099	1·386	1·4355
0·100	1·400	1·4500

poured into a beaker, and the washings from the absorption tube added. A few drops of litmus or other indicator are added, and the red solution titrated with the decinormal ammonia till it turns blue.

Taking the number of c.c. of acid used as $=$A,
V $=$ volume of acetylene liberated,

$$V : (50-A)\ 0{\cdot}0017 = 1{,}000 : x.$$

$$x = \text{gr. of ammonia in 1 litre of acetylene} = \frac{(50-A)\ 1{\cdot}7}{V}.$$

1 gr. ammonia at 0° C. and 760 mm. $=$ 1,306·3 c.c., hence the vol. of ammonia $(50-A)\ 0{\cdot}0017 \times 1{,}306{\cdot}3$ c.c. $= (50-A)\ 2{\cdot}22$ c.c.

$$V : (50-A)\ 2{\cdot}22 = 100 : x.$$

$$x = \text{vol. per cent. of ammonia} = \frac{(50-A)\ 2{\cdot}22}{V}.$$

Example—

No. of c.c. of decinormal solution needed to neutralise the 50 c.c. of decinormal sulphuric acid after absorption of ammonia, A $=$ 36·9.

V $=$ vol. of acetylene at 0° C. and 760 mm. $=$ 17,200 c.c.

$$x = \frac{(50-36{\cdot}9)\ 222}{17{,}200} = 0{\cdot}16 \text{ per cent. of ammonia.}$$

Behaviour of Acetylene with Various Reagents.

Qualitative reactions of Acetylene

Phillips[1] has studied the effect of various reagents upon acetylene, and the results he obtained may be summarised as follows:—

Palladium chloride. Red brown ppt.; no reduction; very sensitive.

Platinum chloride. Unchanged both in the cold and at 100° C.

Gold chloride. Sudden reduction of black or blue-black gold, which differs markedly from the red-brown precipitated gold.

Gold chloride and potassium hydrate. No reaction when cold; traces of reaction at 100° C.

Silver nitrate. White ppt.; very sensitive.

Ammoniacal silver nitrate. White gelatinous ppt.; a 10 per cent. solution turns solid like starch.

[1] *Zeitsch. f. Anorg. Chem.* 6, 240.

Indium tetrachloride. Unchanged when cold; reduced after a week or when boiled.

Potassium rhutenate. Very little reduction.

Ceric sulphate. Slowly discoloured.

Potassium permanganate. Turns brown suddenly.

Potassium permanganate and sulphuric acid. Suddenly bleached.

Solid potassium permanganate and sulphuric acid. Slow evolution of carbon dioxide.

Potassium chromate and sulphuric acid. Unchanged when cold and at 100° C.

Osmium tetroxide. Sudden black metallic ppt.

Copper sulphate with and without ammonia. Unchanged.

Ferric chloride. Slowly reduced to ferrous chloride.

Calcium hypobromide. Slow evolution of carbon dioxide.

Hydrogen peroxide and calcium hydroxide. Unchanged.

Potassium bismuthate. Unchanged.

Potassium ferricyanide. Unchanged.

Iodine in potassium iodide. Unchanged.

Ammoniacal cuprous chloride. Red ppt.

Chromic sulphate. Unchanged.

Mercuric chloride. White ppt.; very sensitive.

Iodine pentoxide. Reduced at 90° C. with formation of iodine and carbon monoxide.

For all scientific and practical purposes, the best and most sensitive reagent is ammoniacal cuprous chloride. Berthelot in 1860 showed that one two-hundredth of a milligram could be detected. When a few bubbles of acetylene are passed through water and a little ammoniacal cuprous chloride are added, the characteristic red copper-acetylene is at once formed.

The precipitates obtained from silver nitrate or from ammoniacal silver nitrate are very sensitive as reac-

tions, but not as characteristic as the copper reaction. Chavastelon[1] uses this reaction for quantitative estimation of acetylene.

$$C_2H_2 + 3AgNO_3 = Ag_2C_2 \cdot AgNO_3 + 2HNO_3$$

He makes this reaction in Raoult's absorption eudiometer, and estimates the acetylene by re-titration of the nitric acid formed; thus one molecule of acetylene corresponds to two molecules of nitric acid.

[1] *Compt. Rend.* 124, 1,364.

Part III

LEGAL ENACTMENTS OF VARIOUS COUNTRIES

PATENTS AND APPENDIX

LEGISLATION RELATING TO CALCIC CARBIDE AND ACETYLENE

GREAT BRITAIN.

EARLY in 1897, an Order in Council was issued placing carbide of calcium under the Petroleum Acts, not with any intention of hampering the industry, but with the object of bringing before the notice of the public that in the use of the new illuminant acetylene and in the employment of carbide of calcium, from which it is evolved, reasonable precautions would have to be taken. This action of the Home Department cannot be too strongly commended, and if it seems to some that it may have retarded the development of the industry, it must also be borne in mind that the injury of persons by avoidable accidents would have retarded it still more, and it is satisfactory to note that in this country we have not had to deplore such accidents as have occurred in Paris and Berlin, and also in the United States. It is true that these accidents were chiefly due to the storage of liquefied acetylene in cylinders under very high pressures, the use of which is prohibited in this country, still, but for legislation, similar accidents would probably have occurred here. Legislation

The public hearing of these accidents through the Press, could not of course be expected to distinguish between liquid acetylene, stored at a pressure of 700 lbs. to the square inch, and gaseous acetylene, at low pressures, which, with ordinary care, can be quite safely generated in properly constructed apparatus.

By an Order in Council issued in November, 1897, acetylene gas, when liquid or when highly compressed, was very properly brought under the Explosives Acts, but with the proviso that if it could be shown to the satisfaction of the Secretary of State that acetylene in any form or condition was not explosive, an exemption might be granted. Order in Council, November, 1897

Exemption was subsequently granted for certain admixtures of acetylene and oil gas on the initiative of the Acetylene Illuminating Company.

ACETYLENE

The following Orders in Council and Order of the Secretary of State have been issued dealing with carbide of calcium and acetylene :—

PETROLEUM ACT, 1871.

CARBIDE OF CALCIUM.

Order in Council of 26th February, 1897*: Published in the "London Gazette" of 2nd March,* 1897.

Petroleum Act, 1871

At the Court at Windsor, the 26th day of February, 1897.

Present: The Queen's Most Excellent Majesty in Council.

Whereas it is provided by the Petroleum Act, 1871, that Her Majesty may, from time to time, make, revoke, and vary Orders in Council directing that the said Act or any part thereof shall apply to any substance, and that the said Act or the part thereof specified in any such Order shall, during the continuance of the Order, apply to such substance, and shall be construed and have effect as if such substance had been included in the definition of Petroleum to which that Act applies, subject to the following qualifications :—

1. The quality of any substance to which this Act is directed by Order in Council to apply which may be kept without a license, shall be such quantity only as is specified in that behalf in such Order, or if no such quantity is specified no quantity may be kept without a license.
2. The label on the vessel containing such substance shall be such as may be specified in that behalf in the Order.

And whereas the Petroleum Act, 1879, and the Petroleum (Hawkers) Act, 1881, are to be construed as one with the Petroleum Act of 1871, and may, together with such Act, be cited as the Petroleum Acts, 1871 to 1881.

And whereas Carbide of Calcium presents dangers similar to those presented by Petroleum.

Calcium Carbide under the Petroleum Act

Now, therefore, in pursuance of the above-mentioned provisions of the Petroleum Act, 1871, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that the undermentioned parts of the Petroleum Acts, 1871 to 1881, shall apply to the said substance, Carbide of Calcium, in the same manner as if the said substance were Petroleum to which the Acts apply, viz. :—

The whole of the Petroleum Acts, 1871 to 1881, except :—

(*a*) So much of Section 6 of the Petroleum Act, 1871, as specifies the nature of the label to be on the vessel, in lieu of which the label shall be as hereinafter provided.

(*b*) So much of Section 7 of the Petroleum Act, 1871, as relates to the exemption from such Section of small quantities under certain specified conditions, and no quantity of Carbide of Calcium may be kept except in pursuance of such license as in the said Section 7 is provided.

(*c*) So much of Section 11 of the Petroleum Act, 1871, as relates to the testing of samples taken by an Officer of the Local Authority under the powers conferred by such Section.

(*d*) So much of the Petroleum Act, 1879, as relates to the testing of Petroleum.

(*e*) So much of the Petroleum Act, 1881, as relates to the Hawking of Petroleum.

The label on the vessel containing the said Carbide of Calcium shall bear in conspicuous characters the words "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution: "The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and with the addition :—

(*a*) In the case of a vessel kept, of the name and address of the consignee or owner.

(*b*) In the case of a vessel sent or conveyed, of the name and address of the sender.

(*c*) In the case of a vessel sold or exposed for sale, of the name and address of the vendor.

This Order shall come into effect on the 1st of April, 1897.

C. L. PEEL.

Exemption for small quantities of carbide

At the Court at Windsor, the 7th day of July, 1897. Present: The Queen's Most Excellent Majesty in Council.

Whereas it is expedient to exempt small quantities of Carbide of Calcium, when kept under certain conditions, from the operation of the Order in Council of the 26th February, 1897, in virtue of which certain parts of the Petroleum Acts, 1871 to 1881, are applied to Carbide of Calcium in the same manner as if the said substance were Petroleum, to which the Act applies.

Now, therefore, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that notwithstanding anything to the contrary in the said Order in Council, the quantity of Carbide of Calcium which may be kept with or without a license shall be as follows :—

(*a*) Where it is kept in separate substantial hermetically closed metal vessels containing not more than 1 lb. . . . . 5 lbs.

(*b*) Where it is kept otherwise . . . . None

and the said Order in Council shall be deemed to be amended accordingly.

(Signed) C. L. PEEL.

EXPLOSIVES ACT, 1875.

ACETYLENE—LIQUID OR COMPRESSED.

Explosives Act, 1875, Liquid Acetylene

Order in Council the 26th day of November, 1897.

At the Court of Windsor, the 26th day of November, 1897.

Present: The Queen's Most Excellent Majesty in Council.

Whereas by Section 104 of the Explosives Act, 1875, it is enacted that Her Majesty may by Order in Council, declare that any substance which appears to Her Majesty to be specially dangerous to life or property by reason either of its explosive properties, or of any process in the manufacture thereof being liable to explosion, shall be deemed to be an explosive within the meaning of the said Act, and the provisions of the said Act (subject to such exceptions, limitations, and restrictions as may be specified in the Order) shall accordingly extend to any such substance in like manner as if it were included in the term explosive in the said Act.

And whereas Acetylene when liquid or subject to a certain degree of compression is specially dangerous to life or property by reason of its explosive properties.

Now, therefore, Her Majesty is pleased by and with the advice of Her Privy Council to order and declare, and be it ordered and declared as follows:—

Order *re* Acetylene when liquid or compressed

Acetylene when liquid or when subject to a pressure above that of the atmosphere capable of supporting a column of water exceeding one hundred inches in height and whether or not in admixture with other substances, shall be deemed to be an explosive within the meaning of the said Act, subject to the following exception: that if it be shown to the satisfaction of the Secretary of State that Acetylene, declared to be explosive by this Order when in admixture with any substance, or in any form or condition, is not possessed of explosive properties the Secretary of State may by Order exempt such Acetylene from being deemed to be an explosive within the said Act.

And whereas by Section 43 of the Explosives Act, 1875, it is provided that Her Majesty from time to time by Order in Council, may prohibit, either absolutely or except in pursuance

of a license of the Secretary of State under the said Act, or may subject to conditions or restrictions the manufacture, keeping, importation from any place out of the United Kingdom, conveyance, and sale, or any of them, of any explosive which is of so dangerous a character that in the judgment of Her Majesty it is expedient for the public safety to make such Order.

And whereas it is in the judgment of Her Majesty expedient for the public safety that Acetylene, when an explosive within the meaning of this Order, shall be prohibited.

Now, therefore, in pursuance of the above-mentioned provision of this Act, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that Acetylene declared to be an explosive by this Order shall be prohibited from being manufactured, imported, kept, conveyed, or sold.

C. L. PEEL.

ORDER OF SECRETARY OF STATE, NO. 5.

Compressed Acetylene mixed with Oil-gas

Explosives Act, 1875 (38 Vict. c. 17).

Order of Secretary of State relating to Compressed Acetylene in admixture with Oil-gas.

Whereas by an Order in Council, dated 26th November, 1897, made under Section 104 of the Explosives Act, 1875, it is declared that Acetylene when liquid or when subject to a certain degree of compression shall be deemed to be an explosive by the said Order when in admixture with any substance, or in any form or condition, is not possessed of explosive properties, the Secretary of State may by Order exempt such Acetylene from being deemed to be an explosive within the meaning of the said Act.

And whereas it has been shown to the satisfaction of the Secretary of State that Acetylene when in admixture with a gas manufactured from mineral oil (hereinafter referred to as Oil-gas) in certain proportions and not compressed beyond a certain pressure is not possessed of explosive properties.

Now, therefore, in exercise of the powers aforesaid, I, one of Her Majesty's Principal Secretaries of State, hereby order as follows:—

Acetylene in admixture with Oil-gas in a proportion not exceeding twenty parts by volume of Acetylene in every one hundred parts of the mixture, when subjected to a pressure not exceeding one hundred and fifty pounds to the square inch, shall not be deemed to be an explosive within the meaning of the said Act.

Provided that the Acetylene and Oil-gas shall be mixed together in a chamber or vessel before the gases are subjected to compression.

(Signed) M. W. Ridley.

Whitehall,
28th March, 1898.

Abstract of the Petroleum Acts, 1871 to 1881.

Abstract of the Petroleum Acts, 1871–1881

As applied to the Storage and Carriage of Carbide of Calcium by an Order in Council of 26*th February*, 1897.

Prepared by the Acetylene Illuminating Company, manufacturers of Carbide of Calcium, for the use of Local Authorities and others, and reprinted by permission of the Company.

Act, 1871.—An Act for the safe-keeping of Petroleum and other substances of a like nature, August 21st, 1871 (34 & 35 Vict. c. 105).

Sections 1 and 2 deal with the title of the Act and the interpretation of certain terms, such as "Borough," "Harbour Authority," "Court of Summary Jurisdiction," etc.

Section 3 gives the definition of Petroleum and application of the Act thereto when tested in the manner set forth. It is partly repealed by the Act of 1879.

Note.—The Order in Council gives no definition of Carbide of Calcium, nor are any rules laid down as to the method of testing. But it is proposed only to grant licenses to keep "commercially" pure Carbide of Calcium—*i.e.* which contains no impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously.

Section 4 deals with bye-laws as to carriage by ship.

Section 5 requires notice to be given to Harbour Authorities by owner or master of the carrying ship.

Note.—Any contravention of bye-laws in force, or omission to give notice, entails heavy penalties.

Section 6 deals with the label to be affixed to vessels containing Petroleum, and as modified for Carbide of Calcium now reads as follows :—

Labelling packages of Calcic Carbide

Where any Carbide of Calcium, to which this Act applies,

(*a*) Is kept at any place, except during the seven days next after it has been imported; or

(*b*) Is sent or conveyed by land or water between any two places in the United Kingdom; or

(*c*) Is sold or exposed for sale;

the label on the vessel containing the said Carbide of Calcium shall bear in conspicuous characters the words "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and with the addition—

(*a*) In the case of a vessel kept, of the name and address of the consignee or owner;

(*b*) In the case of a vessel sent or conveyed, of the name and address of the sender;

(*c*) In the case of a vessel sold or exposed for sale, the name and address of the vendor.

All Carbide of Calcium to which this Act applies which is kept, sent, conveyed, sold, or exposed for sale, in contravention of this section, shall, together with the vessel containing the same, be forfeited, and in addition thereto the person keeping, sending, or exposing for sale the same shall for each offence be liable to a *penalty* not exceeding Five Pounds.

Section 7 has been modified, and now stipulates that no Carbide of Calcium shall be kept except in pursuance of a license given by Local Authorities. All Carbide of Calcium kept in contravention of this section shall together with the vessel containing the same be forfeited, and in addition thereto the occupier of the place in which such Carbide is so kept shall be liable to a *penalty* not exceeding *Twenty Pounds* a day for each day during which such Carbide is so kept.

Section 8 gives the definition of Local Authorities. This definition has been modified. and we are informed that *the Local Authorities under* these Acts as altered by the Local Government (England and Wales) Act, 1888 (51 and 52 Vict. cap. 41), and the Local Government Act, 1894 (55 and 57 Vict. cap. 73), are now as follows:—

(A) In any harbour within the jurisdiction of a harbour authority (whether or not situated within the jurisdiction of any other local authority).	The Harbour Authority.

(B) In the following districts, except so much as is part of a harbour.

(*a*) In the City of London.	Corporation of City of London.
(*b*) In the Metropolis (outside the City of London).	London County Council.
(*c*) In any borough in England, Wales, Scotland, or Ireland.	Town Council.
(*d*) In any place in Ireland within the jurisdiction of any Trustees or Improvement Commissioners.	The Trustees or Improvement Commissioners.
(*e*) In any place in Scotland within the jurisdiction of Police Commissioners or Trustees exercising functions of Police Commissioners.	The Police Commissioners or Trustees.
(*f*) In any place where there is no Local Authority, as before defined:	
(1) In England and Wales.	The District Council.
(2) In Ireland.	The Justices in Petty Sessions.
(3) In Scotland.	County Justices sitting as Judges in the Justice of Peace Court.

Section 9 deals with the mode of granting licenses, and reads as follows :—

Granting Licenses

" *Licenses in pursuance of this Act shall be valid if signed by two or more* of the persons *constituting the Local Authority*, or executed in any other way in which other licenses, if any, granted by such Authority are executed. Licenses may be granted for a limited time, and may be subject to renewal or not in such a manner as the Local Authority think necessary."

" *There may be annexed to any such license* such conditions as to *the mode of storage*, *the nature and situation of the premises* in which, and the nature of the goods with which Carbide of Calcium to which this Act applies is to be stored, *the faculties for the testing of such Carbide of Calcium from*

time to time, the *mode of carrying such Carbide of Calcium within the district of the Licensing Authority*, and generally as to the safe keeping of such Carbide of Calcium as may seem expedient to the Local Authority."

"Any licensee violating any of the conditions of his license shall be deemed to be an unlicensed person. There may be charged in respect of each license granted in pursuance of this Act such sum, *not exceeding five shillings*, as the Local Authorities may think fit to charge."

Section 10 sets out the remedy in case of refusal of license and reads thus :—

Refusal of License

"If on any application for a license under this Act the Local Authority *refuse* the license, or *grant the same only on conditions with which the applicant is dissatisfied*, the Local Authority shall, if required by the applicant, deliver to him in writing under the hand or hands of one or more of the persons constituting the Local Authority, *a certificate of the grounds on which they refused the license or annexed conditions to the grant thereof.*"

"The applicant within ten days from the time of the delivery of the certificate may transmit the same to a Secretary of State if the application is for a license in England or Scotland, and to the Lord Lieutenant if the application is for a license in Ireland, together with a memorial, praying that notwithstanding such refusal the license may be granted, or that the conditions may not be imposed, or may be altered or modified in such manner and to such extent as may be set forth in such memorial."

"It shall be lawful for the Secretary of State, or the Lord Lieutenant, if he thinks fit on consideration of such memorial and certificate, and if he thinks it necessary or desirable after due enquiry and a report by such person as he may appoint for that purpose to grant the license paid for, either absolutely or with such conditions as he thinks fit, or to alter or modify the conditions imposed by the Local Authority; and the license so granted, or altered and modified, as the case may be, when certified under the hand of a Secretary of State or the Lord Lieutenant, shall be to all intents as valid as if granted by the Local Authority."

Taking Samples

Section 11.—Relates to the testing of samples of Petroleum by officer or local authority, and is now modified (see foot note after Section 3 herein), but any officer authorized by the Local Authority may purchase any Carbide of Calcium from any dealer in it, or may on producing a copy of his appointment purporting to be certified by the clerk or some member of the Local Authority, or producing some other sufficient authority

require the dealer to show him every or any place and all or any of the vessels in which any Carbide of Calcium in his possession is kept, and to give him samples of such Carbide of Calcium on payment of the value of such samples.

Section 12.—Sets out the penalty for obstructing the officer or refusing information, and reads as follows:—

> "Any dealer who refuses to show to any officer authorized by the Local Authority every or any place or all or any of the vessels in which Carbide of Calcium in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such Carbide of Calcium on payment of the value of such samples, or who wilfully obstructs the Local Authority or any officer of the Local Authority in the execution of this Act shall incur a *penalty* not exceeding *Twenty Pounds.*"

Section 13.—Authorizes search for Carbide of Calcium if any court of summary jurisdiction is satisfied by information on oath that Carbide of Calcium is being kept, sent, conveyed, or exposed for sale within the jurisdiction of such court in contravention of the Act. Any Carbide of Calcium so found is liable to be forfeited, and any person obstructing the search or authorizing obstruction is liable to a penalty not exceeding Twenty Pounds in addition to forfeiture of the goods.

Section 14.—By this section Her Majesty may from time to time make, revoke, and vary Orders in Council, directing this Act or any part thereof to apply to any substance other than Petroleum.

NOTE.—It is under this section that the Order in Council applying the Petroleum Acts to Carbide of Calcium came into effect.

Section 15.—Deals with mode of recovery of penalties, etc.

Section 16.—Is a reservation Clause for maintaining previous powers with respect to inflammable substances.

Section 17.—Repeals certain Acts.

Section 18, and last, states the duration of the Act. (This was extended by the Petroleum Act of 1879, and continues in force until otherwise directed by Parliament.)

An Act to continue and amend the Petroleum Act, 1871, 11th August, 1879 (42 and 43 Vict. c. 47).

With the exception of Section 4 continuing in force the Petroleum Act of 1871, until otherwise directed by Parliament the whole of this Act practically refers to the testing of

Petroleum, and is therefore excepted from the Order in Council dealing with Carbide of Calcium.

An Act to regulate the hawking of Petroleum, and other substances of a like nature, 27th August, 1871.

This Act is construed as one with the Petroleum Acts, 1871 and 1879, and together with those Acts is cited as the Petroleum Acts, 1871 to 1881. So far, however, as Carbide of Calcium is concerned, this Act of 1881 is in totality excepted from the Order in Council.

By an Order in Council held 7th July, 1897, it has been prescribed that 5 lbs. of Carbide of Calcium may be kept without a license, *provided* it be kept in separate substantial hermetically closed metal vessels containing not more than 1 lb. each.

EXPLOSIVES ACTS.

Explosives Acts

It would serve no useful purpose to give an abstract of the Explosives Acts, as these only apply to liquid Acetylene stored at a pressure of 600 to 700 lbs. to the square inch, and to acetylene when subject to a pressure above that of the atmosphere capable of supporting a column of water exceeding 100 inches in height equal to 3·6 lbs. per square inch.

Any apparatus for generating acetylene in which this latter pressure is exceeded would be prohibited under the Act. In most generators the pressure does not even approach 100 inches of water pressure.

PETROLEUM ACT AND LOCAL AUTHORITIES.

Petroleum Act and Local Authorities

The whole of the Petroleum Acts apply to Carbide of Calcium in the same manner as if the said substance were petroleum, except as shown in the foregoing abstract.

Probably, Local Authorties will be guided in some measure by the interpretation given to the Order in Council by the London County Council, and the Corporation of London, as these authorities have had the advantage of the assistance of the Home Office and of competent scientists in framing regulations and suggestions.

A copy of the abstracts issued by the London County Council, and the Corporation of London, with a copy of their forms of application and copy of their forms of license is appended hereto, but it will be observed that the abstracts have no legal validity, and it is optional to all Local Authorities to modify the suggestions made in any manner they think desirable.

CITY OF LONDON.

City of London Petroleum Acts, 1871 to 1881

PETROLEUM ACTS, 1871 TO 1881.

ORDER IN COUNCIL, 26TH FEBRUARY, 1897.

The Local Government (England and Wales) Act, 1888.

CARBIDE OF CALCIUM LICENSE.

Carbide License

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, and the Order in Council, dated the 26th February, 1897, the Mayor and Commonalty and Citizens of the City of London (hereinafter called the Corporation) being the Local Authority for the said City, DO HEREBY grant License to..............................of.............................for the period of 12 calendar months from the..................to keep.......................of Carbide of Calcium, to which the Acts and such Order in Council apply, and as defined in the said Acts and Order in Council, on the premises situate at....................in the Parish of....................and within the City of London, subject to the conditions following, that is to say :—

Conditions for storing Calcic Carbide

1. The Carbide of Calcium to be kept only for use on the premises, and not for sale.

2. That the Carbide of Calcium, except when actually being used in generating Acetylene Gas, be kept only in strong metal vessels, so constructed as to exclude water and atmospheric moisture.

3. That the vessel or vessels containing the Carbide of Calcium be kept in the place of storage approved of by the City Surveyor ; that such place of storage be exclusively appropriated to the purpose ; and that the building within which it is comprised be not a dwelling-house, or inhabited.

4. That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorized officer of the Corporation last before the granting of this License.

5. That not more than 112 lbs. of Carbide of Calcium be kept in any one vessel, and that only one vessel be opened at one time.

6. That every storage vessel of a greater capacity than 2 lbs. be secured with a lock or be kept in a locked receptacle so as to prevent unauthorized persons having access to the contents.

7. That when a locked receptacle is provided for the storage of the vessels containing the Carbide of Calcium, no other substance shall be deposited or kept in such receptacles.

8. That the Carbide of Calcium shall be kept only in the metal vessels which have been approved of by the City Surveyor.

All these several matters to be at all times kept in good order and repair, and rendered secure and perfect.

9. That every storage vessel containing Carbide of Calcium bear a label with the words "Carbide of Calcium," "Dangerous, if not kept dry," in conspicuous characters thereon, and with the following caution: "The contents of this package are liable, if brought into contact with moisture, to give off a highly inflammable gas."

10. That Carbide of Calcium be only conveyed to or from the licensed premises in closed vessels.

11. That the vessels containing Carbide of Calcium be only opened upon the licensed premises at or immediately adjoining the place of storage, and for the time necessary for removing the Carbide of Calcium, or for the re-filling of the vessels, and that, during such removal or re-filling, every reasonable precaution be adopted for preventing moisture being brought into contact therewith, as well as for guarding against the risk of ignition of any gas which may be liberated.

Generating Apparatus

12. That the apparatus for generating and storing the gas yielded by Carbide of Calcium be placed in a well-ventilated outbuilding, and that no artificial light, capable of igniting inflammable gas, be taken into or near the building used for this purpose.

13. That escape of gas from the apparatus be carefully guarded against, and provision made against the occurrence of undue pressure by the employment of a safety valve connected with a pipe discharging into the open air. The apparatus also to be furnished with a pressure gauge.

14. That satisfactory provision be made against dangerous development of heat.

15. That any residue of Carbide of Calcium be at once mixed with at least ten times its bulk of water on being removed from the generator.

16. That no person be entrusted with the charge of a gas-generating apparatus until he has been properly instructed in its management.

17. That all Carbide of Calcium received upon the premises be at once taken to the place of storage, and that Carbide of Calcium taken from the place of storage for delivery or otherwise be at once removed from the premises.

18. That the Licensee do take effectual precautions for pre-

venting unauthorized persons and all persons under the age of 15 years from obtaining access to the place of storage.

19. That due precaution be at all times taken for the prevention of accident from fire.

20. That every authorized officer of the Corporation be at all times allowed free access to the premises of the Licensee for the purpose of ascertaining if the above conditions are properly observed, and of obtaining samples of Carbide of Calcium, at the cost of the Corporation, for the purpose of being tested; and that the Licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

21. Nothing in this License is to absolve the Licensee from liability to observe and carry out the special requirements and provisions contained in the said Acts and Order in Council, and any breach of the above conditions shall operate as a forfeiture of the License.

By Order of the Corporation,

....

GUILDHALL, LONDON, *Town Clerk.*

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This License is not transferable, and alone operates from the day on which it is taken up by the Licensee.

The attention of the Licensee is specially directed to the following extract from Section 9 of the Petroleum Act, 1871 :—

> "Any Licensee violating any of the conditions of his license shall be deemed to be an unlicensed person."

N.B.—Should it be desired to renew this License, an application for such purpose must be sent to the Town Clerk, Guildhall, not later than

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CITY OF LONDON.

PETROLEUM ACTS.

Keeping, Selling, and Conveying
CARBIDE OF CALCIUM.

Storage, Carriage and Sale of Carbide

By an Order in Council, dated 26th February, 1897, it is directed that the Petroleum Act, 1871 (34 and 35 Vict. c. 105), shall apply to Carbide of Calcium. This material can, therefore, only be legally kept under a License granted by the Local Authority, even in the smallest quantities, and whether for sale or for private use.

The Local Authority for the City of London is the Corporation, and application should accordingly be forthwith made to the Town Clerk, Guildhall, E.C., by all those who are keeping or desire to keep Carbide of Calcium within the City.

A printed Form of Application will be supplied.

Every application should be accompanied by a Statement setting forth :—(*a*) The maximum quantity proposed to be kept; (*b*) Whether it is to be kept for sale or for use; (*c*) The proposed place and method of storage.

Storage of Carbide

In granting Licenses the Corporation will, as far as possible, be guided by the following principles :—

1. Strong metal vessels, so constructed and closed as to exclude water and atmospheric moisture, should be used for keeping Carbide of Calcium, and these vessels should only be opened during such time as is necessary for the removal of the required portion of their contents or for refilling. The maximum contents should not exceed 112 lbs. Copper should not be used in the construction of the vessels.

2. Every storage vessel of a greater capacity than 2 lbs. should be secured with a lock or be kept in a locked receptacle, so as to prevent unauthorized persons having access to the contents.

3. Storage vessels should not be kept in dwelling-houses, but the keeping by holders of Licenses of small quantities in shops, dwellings or workshops, for sale or use, will be permitted under suitable conditions.

4. The Carbide of Calcium must be pure in a commercial sense, *i.e.* it must contain no impurities liable to generate phosphoretted or siliciuretted hydrogen, so as to render the gas evolved liable to ignite spontaneously.

Apparatus for generating Acetylene

5. Apparatus for generating and storing the gas (acetylene) yielded by Carbide of Calcium should be placed in a well-ventilated outbuilding, and no artificial light capable of igniting inflammable gas should be taken into or near the building used for this purpose. An exception to this will be made in the case of portable apparatus taking a charge not exceeding 2 lbs. of Carbide.

6. The apparatus used for generating and holding the gas should be so constructed and used as to guard against the special risks attaching to the production of acetylene from Carbide of Calcium. Therefore :—(*a*) Copper should not be used in the construction of the apparatus; (*b*) The apparatus should be of adequate strength; (*c*) Escape of gas from the apparatus should be carefully guarded against, and provision should be made against the occurrence of undue pressure by the employment of a safety-valve connected with a pipe discharging

into the open air. The apparatus should also be furnished with a pressure-gauge; (*d*) Satisfactory provision should be made against dangerous development of heat; (*e*) The residue of Carbide should be mixed with at least ten times its bulk of water on being removed from the generator; (*f*) No person should have charge of an apparatus until he has been properly instructed in its management.

7. When Carbide of Calcium is:—(*a*) Kept at any place; or (*b*) Sold or exposed for sale, the vessel containing it shall bear a label stating in conspicuous characters the words "Carbide of Calcium," "Dangerous, if not kept dry," and the following caution:—"The contents of this package are liable, if brought into contact with moisture, to give off a highly inflammable gas," and, in addition, the name and address of the owner or vendor. Where the Carbide of Calcium is—(*c*) Sent or conveyed, the vessel containing it must bear a similar label, except that in this case the name and address of the sender is to be substituted. The License may prescribe the conditions under which the Carbide of Calcium is to be conveyed to or from licensed premises.

8. A charge of Five Shillings will be made in respect of each License.

9. Any dealer who refuses to show to any Officer, authorized by the Corporation, every or any place or all or any of the vessels in which Carbide of Calcium in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such Officer samples of such Carbide of Calcium, on payment of the value of such samples, or who wilfully obstructs the Corporation, or any Officer of the Corporation, in the execution of these Acts and the order made thereunder, is liable to a penalty not exceeding Twenty Pounds.

A License is not transferable. It is granted for One Year only, and Applications for Renewal must be made prior to its expiry.

By order of the Corporation,

JOHN B. MONCKTON,

Town Clerk.

NOTE.—This Memorandum does not preclude the Corporation from imposing any further conditions in any particular case, and is intended only for the guidance of Applicants for Licenses.

GUILDHALL, *April*, 1897.

LONDON COUNTY COUNCIL.

London County Council Carbide License

Petroleum Acts, 1871 *to* 1881, *and Order in Council, dated* 26*th February*, 1897.

CARBIDE OF CALCIUM LICENSE.

Reg. No.......

Pursuant to the provisions of the Petroleum Acts, 1871 to 1881, and of the Order in Council, dated 26th February, 1897, the London County Council doth hereby at the request of......... ....grant License to..................... for the period of twelve calendar months from the................. ....to keep.................. ....of Carbide of Calcium on the premises .... in the parish of..and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

Conditions for Storage

That Carbide of Calcium which contains impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously, be not kept under this license.

That Carbide of Calcium be kept only in............................. ....

That Carbide of Calcium, excepting when being actually used in generating Acetylene Gas, be kept only in strong metal vessels so constructed and closed as to prevent the admission of water or atmospheric moisture.

That every such vessel when containing Carbide of Calcium bear a label, stating in conspicuous characters the words, "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the owner or vendor.

That only one vessel containing Carbide of Calcium be opened at one time, and then only for the time necessary for the removal of any required quantity of Carbide, or for the refilling of the vessel.

That not more than 112 lbs. of Carbide of Calcium be kept in any one vessel.

That any quantity of Carbide of Calcium exceeding 2 lbs. in

weight be only kept in a vessel or vessels securely locked, unless such vessel or vessels are in a locked receptacle.

That fire, or any such artificial light as would ignite inflammable gas, be not taken into or near the building or place where Carbide of Calcium is kept or used in quantities exceeding 2 lbs.

That any residue of Carbide of Calcium on being removed from a gas-making apparatus be at once mixed with at least ten times its bulk of water.

That any apparatus containing Carbide of Calcium be only entrusted to the charge of a person properly instructed in its management.

That Carbide of Calcium be sent or conveyed only in strong metal vessels so constructed and closed as to prevent the admission of water or atmospheric moisture, and bearing a label stating in conspicuous characters the words, "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture, to give off a highly inflammable gas," and also the name and address of the sender.

That every authorized Officer of the Council be at all times allowed free access to the premises of the Licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the Licensee do, by himself or his representatives, give any assistance for that purpose which such Officer may require.

By Order of the Council.

....

Clerk of the Council.

Spring-gardens, S.W.

Section 9 *of the Petroleum Act*, 1871, *which applies to Carbide of Calcium, provides that any* "*Licensee violating any of the conditions of his License shall be deemed to be an unlicensed person.*"

THIS LICENSE IS NOT TRANSFERABLE.

Received the sum of Five Shillings in respect of the above License (Provisional Receipt No.   ).

£0 : 5 : 0

Countersigned,

Cashier.

for the Comptroller.

LONDON COUNTY COUNCIL.

Application form for License

PUBLIC CONTROL DEPARTMENT.

Petroleum Acts, 1871 *to* 1881, *and Order in Council, dated* 26*th February*, 1897.

Reg. No..........

Application to the London County Council for a License to keep Carbide of Calcium.

This application should be fully filled up in accordance with the following instructions, and forwarded to the Chief Officer of the Public Control Department, London County Council, 21, Whitehall Place, S.W., with a P.O. or Cheque for 5*s*., payable to order of the London County Council and crossed. This fee will be retained if the license be granted, or returned to the applicant if the license be refused.

State Christian name and Surname of the Applicant. *If a Firm, the names of each Member in full. If a Company, the name of the Company and its Secretary.*	
State situation of the premises for which the license is required.	
State quantity desired.	
State if the Carbide will be kept and sold unopened in the vessels in which it is received, and if not, what will be done with it.	
State in what vessels the Carbide will be kept, capacity of vessels, how closed against moisture, and of what material constructed.	
State (*a*) in what part of the premises the Carbide is to be kept; (*b*) the construction of the store; (*c*) if the store is used for other purposes, and if so what.	

State if the Carbide is to be used for the manufacture of Acetylene Gas, and if so, state—
- (*a*) The make and capacity of the generator.
- (*b*) Particulars as to the building in which it will be placed, if detached from other buildings, and if used for other purposes.
- (*c*) How you propose to dispose of the residue.
- (*d*) If the machine will be in the sole charge of a person properly instructed in its management.

Signature of Applicant..
Trade..
Postal Address..
Date...........................

MIXTURES OF ACETYLENE WITH AIR OR OXYGEN.

It has now been prescribed by a Home Office Order that the use of acetylene in admixture with air or oxygen be prohibited, except where such admixture takes place in the burner at which it is to be consumed.

UNITED STATES OF AMERICA.

In America the regulation of the acetylene industry is dealt with by the Fire Insurance Companies, advised by the Committee on Fire Protection Engineering, and in February, 1899, this body issued the following report:—

Acetylene Gas.

The rapid development of the manufacture of acetylene gas machines has resulted in a greater demand upon the time and attention of the Bureau in this direction during the half-year than that exercised by any other department of the work. It cannot yet be absolutely determined whether lighting by acetylene gas is to be a commercial success. The simplicity of the primary principle involved in its manufacture has led many persons ignorant of common gas practice to construct machines for this purpose, many of which indicate a total lack of appreciation of the explosive qualities of the gas, as well as limited mechanical knowledge.

The gas exhibits dangerous explosive qualities within certain limits of air saturation, and many devices of reasonable mechanical merit have required reconstruction to obviate air mixtures of this character. Excessive and dangerous heating follows the application of small quantities of water to a large bulk of carbide, which is a very general defect in many types of machines.

Up to the present date we have examined the machines of one hundred and twenty-three different manufacturers. Fifty-seven of this number have been finally approved for use. Many of the machines now listed as of satisfactory construction have been practically rebuilt under our direction, certain of the same requiring one, two and three re-examinations, before being considered suitable for use inside buildings.

Tests will be continued along the lines already followed and results promulgated as heretofore by publishing lists of approved and unapproved machines, regularly furnished to subscribers.

The Committee on Lighting, Heating and Patents of the National Board of Fire Underwriters, after consultation with our own and other experts, has promulgated certain fundamental requirements governing the construction and installation of acetylene gas generators which we recommend for your adoption as follows; the same being, as far as they go, in accordance with our past practice in this subject, and very useful in bringing about uniformity of action among the different organizations interested.

Supplementing these, we have furnished all the underwriting organizations in the country with lists of acetylene devices which we have found critically defective, asking their co-operation in securing the necessary improvements. This action on our part has been very favourably received, assurances of active co-operation being returned to us and in some instances approvals previously issued being withdrawn until the machines criticised should be reconstructed in accordance with our established standards of safety.

And later in the year the National Board issued the following rules :—

"The following rules governing the Construction and Installation of Acetylene Gas Machines and the storage of Calcium Carbide are adopted as standard, and should be observed in all cases.

Generators must receive approval before installation.

Liquid Acetylene.—The use of liquid acetylene or gas generated therefrom is absolutely prohibited.

National Board Rules Governing Construction of Acetylene Generators.

1. Must be made of iron or steel, and in a manner and of material to insure stability and durability.

2. Must have sufficient carbide capacity to supply the full number of burners during the maximum lighting period.

NOTE.—This rule removes the necessity of recharging at improper hours. Burners almost invariably consume more gas than their rated capacity, and carbide is not of staple purity; therefore there should be an assurance of sufficient quantity to last as long as light is needed. Another important feature is that in some establishments burners are called upon for a much longer period of lighting than in others, which requires a generator of greater gas-producing capacity.

3. Must be uniform and automatically regulated in its action, producing gas only as immediate consumption demands, and so designed that gas is generated without excessive heating at all stages of the process.

NOTE.—This rule is necessary, because the presence of excessive heat tends to change the chemical character of the gas, and may even cause its ignition.

4. Apparatus not requiring pressure regulators must be so arranged that the gas pressure cannot exceed thirty tenths inches water column (three inches).

5. Must be provided with an escape pipe, which will operate in case of the over-production of gas, and also an attachment acting as an escape or relief in case of abnormal pressure in the machine, and which will carry such excess gas through an escape pipe of at least three-quarter inch internal diameter to a suitable point outside of building, discharging at least twelve feet above ground level, and provided with an approved hood.

NOTE.—Both the above safety vents may be connected with the same escape pipe.

6 Apparatus requiring pressure regulator must be so arranged that the gas pressure cannot exceed three pounds to the square inch. Such apparatus must be provided with additional safety blow-off attachment located between the pressure regulator and the service pipes and discharging to the outer air, the same as provided for in Rule 5.

NOTE.—This is intended to prevent the possibility of undue pressure of gas in the service pipe by failure of the pressure regulator.

7. Must be so arranged that when being charged the back flow of gas from the holder will be automatically prevented, or so arranged that it is impossible to charge the apparatus with-

out first closing the supply pipe to holder, or to other generating chambers, if any.

NOTE.—This is intended to prevent the dangerous escape of gas.

8. Must be so arranged as to contain the minimum amount of air when first started or recharged, and no device or attachment facilitating or permitting mixture of air with the gas, prior to consumption, except at the burners, shall be allowed.

NOTE.—Owing to the explosive properties of acetylene mixed with air, machines should be so designed that such mixtures are impossible.

9. No valves or pet-cocks opening into the room from gas-holding part or parts, the draining of which will allow an escape of gas, shall be permitted, and the condensation from all parts of the apparatus must be automatically removed without the use of valves or mechanical working parts.

NOTE.—Such valves and pet-cocks are not essential; their presence increases the possibility of leakage. The automatic removal of condensation from the apparatus is essential to the safe working of the machine.

10.—The water supply to generator must be so arranged that gas will be generated long enough in advance of the exhaustion of the supply already in the gas-holder to allow of the using of all lights without exhausting such supply.

NOTE.—This provides for the continuous working of the apparatus under all conditions of water feed and carbide charge, and it obviates the extinction of lights through intermittent action of the machine.

11. No carbide chamber of over twenty-five pounds capacity shall be allowed in any machine where water is introduced in small quantities, or where the contact of water with carbide is intermittent.

NOTE.—This tends to reduce the danger of overheating, and provides for the division of the carbide charges in machines of these types of large capacity.

12. Generator must be connected with the gas-holder in such manner that it will, at all times, give open connection either to the gas-holder or to the blow-off pipe into the outer air.

NOTE.—This prevents dangerous pressure within or the escape of gas from generating chamber.

13. Must be so designed that the residuum will not clog or affect the working of the machine, and can conveniently be handled and removed.

14. Covers to generators must be provided, with secure fastenings to hold them properly in place, and those relying on a water-seal must be submerged in at least twelve inches of water.

Water-seal chambers, for covers depending on a water-seal, must be one and a half inches wide and fifteen inches deep, excepting those depending upon the filling of the seal chambers for the generation of gas, where nine inches will be sufficient.

15. Holder must be of sufficient capacity to contain all gas generated after all lights have been extinguished.

NOTE.—If the holder is too small, and blows off frequently after lights are extinguished, there is a waste of gas. This may suggest improper working of the apparatus, and encourage tampering.

16. The bell portion must be provided with a substantial guide to its upward movement, centre guide preferred, and a stop acting about one inch above the blow-off point.

NOTE.—This tends to insure the proper action of the bell, and decreases the liability of escaping gas.

17. A space of at least three-quarters of an inch must be allowed between the sides of the tank and the bell.

18. All water-seals must be so arranged that the water level may be readily seen and maintained.

19. Gas-holders constructed upon the gasometer principle must be so arranged that when the gas bell is filled to its maximum, its lip, or lower edge, shall at all times be submerged in at least nine inches of water.

20. The supply of water to the generator for generating purposes shall not be taken from the water-seal of any gas-holder constructed on the gasometer principle.

NOTE.—This provides for the retention of the proper level of water in the generator.

21. The apparatus shall be capable of withstanding fire from outside causes without falling apart or allowing the escape of gas in volume.

NOTE.—This prevents the use of joints in the apparatus relying entirely upon solder.

22. Gauge glasses, the breakage of which would allow escape of gas, shall not be permitted.

23. Where purifiers are installed, they must conform to the general rules for the construction of other apparatus, and allow the free passage of gas.

24. The use of mercury seals is prohibited.

NOTE.—Mercury has been found unreliable as a seal in acetylene apparatus.

25. Construction must be such that liquid seals shall not become thickened by the deposit of lime or other foreign matter.

26. Apparatus must be constructed so that accidental syphoning of the water is impossible.

27. Flexible tubing, swing joints, packed unions, springs,

chains, pulleys, stuffing boxes, and lead or fusible piping must not be used on apparatus, except where the failure of the part will not vitally affect the working or the safety of the machine.

28. There shall be plainly marked on each machine the maximum number of lights it is designed to supply and the amount of carbide necessary for a single charge.

The above rules are general, and are intended to provide only against the more hazardous defects usually noted in apparatus of this kind. The rules do not cover details of construction nor the proper proportioning of parts. These points are often only developed in the examination required before approval.

Rules Governing the Installation of Acetylene Generators.

It is desirable that all acetylene generators shall be installed outside of insured buildings. (*See* Specifications, rule 15.) But special permission may be granted to install generators inside buildings where they are installed in conformity with the following rules, and approved by an authorized representative.

1. Generators must be placed on substantial foundations and set perfectly level. Where practicable, the foundations shall be of brick, stone, concrete, or iron. If necessarily of wood, they shall be extra heavy, in a dry place, and open to the circulation of air. The foundations must be such that unequal strain is not placed on the generator or connections.

NOTE.—The ordinary board platform commonly used is not satisfactory. Wooden foundations should be of heavy planking, joists or timbers arranged so that the air will circulate around them, and so as to form a firm base. Wood should not be used in the construction of the machine, or to support the several parts.

2. Generators must be placed where water in the same will not freeze. Where they are not intended for use throughout the entire year, all water and gas must be removed at the end of the season.

NOTE.—It is usually necessary to take the bell portion of the holder out, so as to allow all gas to escape. This should never be done in the presence of artificial light or open fire of any kind.

3. Generators to be placed preferably in a large, well-ventilated room. In no case must they be placed in closets or small rooms where artificial light is necessary. If enclosed, the enclosure should be of slatted partitions, permitting the free circulation of air. Rooms must have sufficient height to permit the free and full upward movement of the gasholder or moving parts.

4. Generators to be placed where they can be easily adjusted and operating mechanism readily seen without artificial light, and in no case should they be placed so that their proper action can be easily interfered with by children or careless persons.

Where possible, generators must be placed so as to be well lighted from windows.

5. Generators should be placed at the greatest distance practicable from direct fire heat and artificial light. In no case should they be nearer than 15 feet to direct fire heat, and in no case must they be nearer than ten (10) feet to any gas jet, lamp, lantern, or other source of artificial light.

6. Each generator must be provided with an escape or relief pipe of at least three-quarter inch internal diameter. This pipe must be substantially installed, without traps, and so that any condensation will drain back to the generator. It must be carried to a suitable point outside the building, and terminate in an approved hood located at least 12 feet above ground and remote from windows.

7. The connection from generator to service pipes must be made so that any possible moisture in the pipes will drain back to the generator. Pet-cocks for draining are not permitted.

NOTE.—A valve and by-pass connection should be provided from the service pipe to the blow-off for removing the gas from the holder in case it should be necessary to do so.

8. The schedule of pipe sizes for piping from generator to burners should conform to that commonly used for ordinary gas, but in no case should the feeders be smaller than three-eighths of an inch. The following schedule is advocated :—

$\frac{3}{8}$ inch pipe, 26 feet, three burners.
$\frac{1}{2}$ inch pipe, 30 feet, six burners.
$\frac{3}{4}$ inch pipe, 50 feet, twenty burners.
1 inch pipe, 70 feet, thirty-five burners.
$1\frac{1}{4}$ inch pipe, 100 feet, sixty burners.
$1\frac{1}{2}$ inch pipe, 150 feet, one hundred burners.
2 inch pipe, 200 feet, two hundred burners.
$2\frac{1}{2}$ inch pipe, 300 feet, three hundred burners.
3 inch pipe, 450 feet, four hundred and fifty burners.
$3\frac{1}{2}$ inch pipe, 500 feet, six hundred burners.
4 inch pipe, 600 feet, seven hundred and fifty burners.

The piping must be thoroughly tested, both before and after burners have been installed. Piping should not show loss in excess of two inches within twelve hours when subjected to pressure equal to fifteen inches of mercury.

9. Generators must be installed by persons experienced in the installation of acetylene apparatus. Each installation to be inspected by an authorized representative before the permit is granted.

10. Generators must be of sufficient capacity to furnish gas continuously for all lights supplied and for the maximum lighting period. They must be capable of supplying gas continuously for at least five hours, and for all burners attached.

NOTE.—Owing to the fact that most of the generators examined are found to be overrated and poorly proportioned for the service expected of them, great care should be taken to provide a machine large enough for all conditions of service, and so that recharging at night can be avoided. The following ratings will usually be found advisable:—

(*a*) For dwellings and where machines are always used intermittently, a generator rated to supply *all* of the burners attached should be used.

(*b*) For stores, opera houses, day run factories, and similar service, the generator should have a capacity of from 30 to 50 per cent. in excess of the total capacity of the burners.

(*c*) For saloons, all night or continued service, generators having an excess capacity of from 1 to 200 per cent. over total capacity of burners are almost always necessary.

A small generator should never be installed to supply a large number of lights, even though it seems probable that only a few lights will be used at a time. *An overworked generator adds to the cost of acetylene.*

11. Carbide charges must be sufficient to furnish gas for all burners during the maximum lighting period. In determining charges, the carbide to be estimated as containing 4½ cubic feet to the lb., and the burners as consuming at least 25 per cent. overrated burning capacity.

NOTE.—Some manufacturers prefer to increase the carbide charge in order to supply the rated number of lights for a longer period than five hours. In such cases the generators must be cleaned and recharged at regular stated intervals regardless of the number of lights actually burned.

12. Burners consuming one-half of a cubic foot per hour are considered standard in rating generators. Those having a greater or less capacity will decrease or increase the number of burners allowable in proportion.

NOTE.—Burners usually consume from 25 to 100 per cent. more gas than their rated capacity, depending largely on pressure. The one-half foot burner (so-called) is usually used with best economy.

13. Burning pressures should be from twenty to twenty-five tenths inches water column for best economy. The piping should be such that uniform pressure is furnished to all burners without over-weighting the gasholder. (*See* Rule 8.)

14. Portable acetylene apparatus for temporary, occasional, scientific, educational or experimental exhibitions may be per-

mitted, providing it does not contain more than 3 lbs. of calcium carbide, and providing it complies with rules of installation.

15. *Specifications for Outside Generator House.*

(*a*) In closely built-up districts, outside generator house to be of brick, fireproof, and located at least 10 feet away from other buildings. Where the generator house does not open into or toward the building, it may be placed close to it, providing the separation of 10 feet be clearly impossible. In outlying districts where the generator house can be located 25 feet away from other buildings, it need not be of fireproof construction.

(*b*) Dimensions to be confined to the requirements of the apparatus, allowing convenient room for recharging and inspection of parts; floor to be located at least 12 inches above grade.

(*c*) To be heated by steam, hot water, or hot air, care being taken to insure against freezing in the most severe weather. To be without artificial light, and to be provided with a hooded ventilator in roof, which can be opened and closed from the inside.

(*d*) To be used exclusively for the apparatus or storage of calcium carbide, when not in conflict with other rules, and to be kept under lock and key, so as to prevent molestation.

Rules for the Storage of Calcium Carbide.

1. Calcium carbide in quantities not to exceed 600 lbs. when contained in approved packages, holding not more than 100 lbs. each, must be stored *outside* of insured property in:

(*a*) A waterproof structure or receptacle having the bottom raised at least 4 inches above ground and *located at least ten feet from any building*; or:

(*b*) A magazine constructed of not less than No. 12 gauge iron, the bottom to be fastened to sides by 1½ inch angle iron, the upper edge to be reinforced by a band of iron, the whole to be waterproof and raised at least 4 inches above the ground, and *located preferably away from windows*; or:

(*c*) A fire and waterproof brick vault opening away from the building, with floor raised at least 4 inches above grade.

In all cases the enclosure or receptacle to be used exclusively for this purpose to be without artificial light, and kept under lock and key.

2. Calcium carbide in approved metal cans, holding not more than 2 lbs. each, may be permitted inside insured buildings

when contained in an enclosed magazine or holder constructed in accordance with the following specifications:

(*a*) The holder for these cans must be constructed of galvanized iron not less than No. 18 American gauge, and must have all seams lapped, rivetted, and soldered both inside and out, so as to protect edges and rivets from rust, and form thoroughly watertight joints.

(*b*) The holder to be constructed so that the bottom will be raised at least 6 inches from the floor by means of ventilated rims. These rims to be reinforced where they come in contact with the floor by heavy iron bands, and flared so that they will be at least 6 inches larger at the base than at the top.

(*c*) The holder must be closed at the top with a cover designed to form a water-tight joint by means of a single clamp, and all removable parts must be attached to the holder proper by chains or other approved method.

(*d*) The dimensions of these holders must be so proportioned that not more than 100 pounds of carbide, in metal packages not exceeding 2 pounds each, can be placed in any one holder.

(*e*) Each holder must be kept above the grade of the street, and plainly marked in letters at least 2 inches in height, "CALCIUM CARBIDE—KEEP DRY." The cover must be marked, "KEEP CLOSED."

(*f*) Packages containing not more than 2 lbs. each must be made of metal. Joints not to rely on solder, and cans to be thoroughly watertight.

(*g*) Packages containing not more than 100 lbs. must be made of metal. Seams must be lock-jointed and soldered. The can must be provided with a screwed top, or its equivalent, must be watertight, of sufficient strength to insure handling without rupture, must be wood or iron jacketed and conspicuously marked, "CALCIUM CARBIDE—DANGEROUS IF NOT KEPT DRY."

3. Where calcium carbide is stored in large quantities it must be stored above grade, and in a building especially constructed and used exclusively for this purpose.

Frame buildings for the storage of calcium carbide to be thoroughly dry, waterproof, well ventilated, without artificial light or heat, and located at least 100 feet from any other building.

Fireproof buildings for the storage of calcium carbide to be thoroughly fireproof, thoroughly dry, waterproof, well ventilated, without artificial light or heat, and located at least 50 feet from any other building.

German regulations

GERMAN REGULATIONS FOR THE MANUFACTURE AND USE OF ACETYLENE.

Prussia.

Prussia

Decree of the Prussian Home Office.

The manufacture of Acetylene Gas is considered as a chemical manufacture similar to those mentioned in § 16 of the Law of Industry, and is therefore subject to the same regulations.

Regulations for Acetylene works

Conditions for the Establishment of Acetylene Factories.

1. Acetylene must be generated and compressed in another building than that in which it is liquefied.

If a pressure of more than eight atmospheres is required for the compression of the gas the work must be done in a separate room.

2. No places in which acetylene is manufactured, compressed, or liquefied are allowed to be under rooms in which people are living, or to be connected directly with the same; they must be well lighted and ventilated, and the use of steam or hot water for heating the rooms is obligatory. The doors must open outwards.

3. The places in which acetylene is made, compressed, or liquefied must only be lighted by lamps which are outside and well protected from any communication with the room, or by electric lamps with double bulbs. Switches and fuses must not be in the same room.

4. In order to protect the carbide from moisture, it must be kept in water-tight vessels, and only as much as is wanted at the time should be taken out. The vessels must be stored in dry, well-lighted, and well-ventilated places: cellars must not be used to keep them in.

5. The grinding of the carbide must be effected with every precaution against the formation of dust. The workmen must be supplied with respirators and spectacles.

6. Acetylene gasholders must be erected in the open, or in another place than that in which the generators stand, this place being kept well ventilated.

7. Every acetylene gasholder must be provided with a water manometer, by which one can at any time gauge the extent of the pressure.

8. In order to remove any impurities—phosphuretted hydrogen, arseniuretted hydrogen, sulphuretted hydrogen, ammonia, etc.—a good washer must be put between the generator and holder.

9. The compression of acetylene under a pressure of more than ten atmospheres must only be effected in the cold.

10. When the acetylene has been liquefied, the condenser must be disconnected the moment the compression is over.

11. Those parts of the engines, pipes, and general fittings which come in contact with the acetylene must not be made of copper or have sharp edges. An alloy of copper is, however, permissible for fittings, cocks, and other apparatus in which there is no more than one atmosphere pressure.

12. The water which has been used may only be thrown into public rivers after having been purified and its volume increased five times.

Conditions for the Manufacture of Acetylene for Private and Domestic Purposes.

Regulations for private installations

1. Any one desirous of making acetylene on a smaller scale than is done in factories should notify it to the head officials at the principal police station not later than the first time the generator is in use.

2. Acetylene may not be generated in or underneath places in which people are living, neither may it be made or stored in cellars.

The place where the gas is generated must be separated by a fireproof wall or clear space from places in which people are living; the roof under which the generator is erected must be lightly built.

3. Such places must be well lighted, large, and well ventilated, must only be heated by steam or hot-water pipes, and must not be entered with a lamp. The doors must open outwards.

Neither the ventilating pipes of these places nor of the generator itself must end in a chimney, but should be led out above the roof.

4. The apparatus for the generation and storage of the gas must be so made as to prevent the creation of a pressure of more than one atmosphere.

5. No part of the generating apparatus, gasholder, or pipes must be made of copper.

6. Quantities of more than 10 kg. (22 lbs.) of calcium or other carbide may be stored only in dry, well-lighted, and well-ventilated places packed in water-tight vessels. Their storage is forbidden in cellars. The vessels must bear the inscription, "Carbide: dangerous if not kept dry."

7. The vessels in which liquefied acetylene is to be kept must be marked with white paint and bear the inscription, "Liquefied acetylene—inflammable," besides giving the nett weight and

capacity expressed in litres. They must also have been tested under a pressure of 250 atmospheres.

8. The proportion of the quantity of acetylene in a bottle to its capacity must not be more than 1 kg. (2·2 lbs.) to 3 litres.

9. Cylinders for compressed acetylene must be marked with the inscription, "Acetylene—inflammable," besides giving the highest pressure allowed. They must have been tested under a pressure twice as great as the one allowed.

10. The vessels filled with liquefied or compressed acetylene must be protected from the sun's rays and the heat from stoves.

11. Liquefied and compressed acetylene must only be put in vessels of which no part consists of copper or its alloys.

12. Paragraphs 1, 2, and 3 do not apply to portable acetylene lamps nor to those lamps in which the burner is directly connected with the generating apparatus.

To those who, at the publication of these police regulations, are, with the consent or knowledge of the local police authorities, already working acetylene-generating apparatus, a term of twelve months, beginning on the day that these regulations come into force, can be granted to comply within that time with the rules given in § 2 and the first part of § 3.

Exceptions

The above regulations do not apply to—

(*a*) Installations for the manufacture of gas worked on a large scale, and for which, according to § 16 of the General Industrial Law, a special license is required.

(*b*) Scientific Government Institutes, in so far as acetylene is made and used by them for the purposes of teaching and study.

13. Infringements of these regulations, unless thereby any heavier punishment be incurred according to any law already in existence, shall be punishable by a fine of not more than 60 marks (£3), and any one unable to pay such a fine shall be committed to prison.

14. The above police regulations come into force on the day of their publication, and at the same time the police regulations of December 19th, 1896, will be cancelled.

Berlin

BERLIN.

Notification of Nov. 25th, 1897

Notification.—In reference to the regulations given above, be it known to the public that installations for the manufacture of acetylene, in so far as they are worked on a large scale, are to be considered as being "chemical factories," as mentioned in § 16 of the Imperial Industrial Law.

Liquefied acetylene is to be considered as an "explosive substance," as mentioned in the Law for criminal use of explosive substances endangering the public safety, dated June 9th, 1884.

LEGAL ENACTMENTS

To those persons who, according to the police regulations of December 19th of last year, 1896, have received permission to manufacture acetylene, a term of twelve months from the day upon which the above regulations come into force can be granted, to comply within that time with the rules given in §§ 1, 2 and 3 of the above regulations. Applications must be made without delay to the office of the Director of Police.

Berlin, *November* 25*th*, 1897.

The above regulations have been brought into force by the authorities of the following Prussian states :—

Prussian States in which these regulations are in force

Town.	Date of regulation.	No.	Date of publication.
Aachen	Nov. 15, 1897	49	Nov. 18, 1897
Arnsberg	Jan. 25, 1898	5	Jan. 29, 1898
Aurich	Jan. 17, 1898	3	Jan. 21, 1898
Breslau	Dec. 17, 1897	52	Dec. 25, 1897
Bromberg	Dec. 10, 1897	50	Dec. 16, 1897
Danzig	Feb. 28, 1898	10	Mar. 5, 1898
Dusseldorf	Dec. 14, 1897	50	1897
Erfurt	Jan. 24, 1898	4	Jan. 29, 1898
Frankfurt	Dec. 18, 1897		
Gumbinnen	Dec. 2, 1897	49	1897
Hanover	Dec. 27, 1897	54	Dec. 12, 1897
Hildesheim	Dec. 4, 1897	50	Dec. 10, 1897
Kassel	Dec. 24, 1897	52	Dec. 29, 1897
Koblenz	Dec. 16, 1897	57	Dec. 23, 1897
Koln	Dec. 15, 1897	51	Dec. 22, 1897
Konigsburg	Nov. 20, 1897	48	Dec. 2, 1897
Koslin	Jan. 22, 1898	4	Jan. 27, 1898
Liegnitz	Dec. 4, 1897	51	Dec. 18, 1897
Luneburg	Dec. 21, 1897		
Magdeburg	Jan. 11, 1898	4	Jan. 22, 1898
Marienwerder	Dec. 13, 1897	51	Dec. 22, 1897
Merseburg	Dec. 14, 1897	51	Dec. 8, 1897
Minden	Jan. 3, 1898	1	1898
Munster	Dec. 18, 1897	1	Jan. 6, 1898
Oppeln	Jan. 3, 1898	1	Jan. 7, 1898
Osnabruck	Nov. 24, 1897	48	Nov. 26, 1897
Posen	Jan. 7, 1898	3	Jan. 18, 1898
Potsdam, Berlin	Nov. 25, 1897	49	Dec. 3, 1897
Potsdam	Dec. 10, 1897	51	Dec. 12, 1897
Schleswig	Dec. 13, 1897	58	Dec. 18, 1897
Sigmaringen	Dec. 27, 1897	1	Jan. 7, 1898
Stade	Jan. 12, 1898	3	Jan. 21, 1898
Stettin	Jan. 11, 1898	2	Jan. 14, 1898
Stralsund	Dec. 22, 1897	2	Jan. 14, 1898
Trier	Dec. 4, 1897	52	Dec. 30, 1897
Wiesbaden	Jan. 8, 1898	49	Dec. 9, 1897

Saxony

SAXONY.

Decree of the Home Office, dated from Dresden
February 28th, 1898.

With the addition of the paragraph given below, which is affixed to § 2 *of the conditions for the manufacture and use of acetylene for private and domestic purposes, the regulations for Saxony are, word for word, the same as those for Prussia, which have been already quoted.*

The applications, which are to be made in small towns at the Mayor's Office, or at the Mayor's or Magistrate's Office in villages, must be returned within three days, and any protests against installations must also be lodged. If there are none, the applications must be signed and delivered to the appointed official.

The Mayor and members of the Town Council must consult Factory Inspectors to convince themselves that the installations are erected in accordance with the rules laid down for them.

Bavaria

BAVARIA.

By decree of the Minister, dated June 16th, 1897, the regulations for the prevention of danger arising from the manufacture and use of acetylene will be drawn up for the time being by the local police authorities.

The regulations made by the authorities of Munich, June 18th, 1898, have been communicated to all the Royal Governments, etc., in order that other police authorities may use them as a guide in the event of their requiring regulations for the same purpose.

Munich

MUNICH.

Local Police Regulations for the City of Munich.

The Magistrate of Munich hereby gives, in accordance with § 368, No. 8, and § 2, No. 14 of the Imperial Penal Code, the local police regulations mentioned hereafter.

1. Private installations for the manufacture of calcium carbide and the generation of acetylene under a pressure of more than half an atmosphere are not allowed within the City of Munich.

The storage and use of acetylene under a pressure of more than half an atmosphere, as well as liquefied acetylene, is forbidden.

The factories are called herein "Chemical factories," as mentioned in § 16 of the Imperial Industrial Law, and are therefore subject to that paragraph.

2. Any one desirous of erecting and working a factory for making and using calcium carbide, or of erecting an acetylene generator, either permanently or for a short period, or wanting to deal in calcium carbide, apparatus for generating acetylene, or in acetylene gas lamps, should previously notify his intention to the Magistrate, in order that the fire insurance inspector may see that the measures for protection against fire have been taken, and all instructions given by the inspector must be carried out. If such a factory, installation, or business is transferred to another person, notice thereof must be duly given. **Munich (cont.)**

3. With installations for lighting with acetylene, a minute description of the whole installation, with plans and also the rules for working the same, confirmed and signed by the person erecting the installation, should be sent in with the notification mentioned in § 2.

They cannot be worked before a written license has been granted by the Magistrate of the City of Munich.

4. Calcium carbide may only be kept in well-closed vessels of a capacity of not more than 50 kg. (110 lbs.), which must be thoroughly protected against damp, and stored in quantities not greater than 300 kg. (660 lbs.), and only such quantities as are required for immediate use should be taken out of these vessels.

The vessels must bear the clear, legible inscription, "Carbide, dangerous if not kept dry." It is not permissible to make or keep acetylene, if a quantity of more than 1 kg. (2·2 lbs.) is used at a time, in places in, or underneath, houses in which people are living, or in cellars.

The places in which the gas is generated must either be at a distance of 10 metres (11 yards) from dwelling places, or separated from them by a fire-proof wall.

Acetylene holders must be erected in the open air or in a well-ventilated place separated from the generator. Every gasholder must be provided with a water manometer, by which the pressure within can be seen at any time.

For removing any impurities — phosphuretted hydrogen, arseniuretted hydrogen, sulphuretted hydrogen, ammonia, etc. —a good washer should be put between the generator and holder.

The places in which acetylene is made must be well lighted and ventilated, and should not be used for any other purpose. They must be heated by steam or hot water, and the ventilating pipes of these places, as well as those of the generators, must not end in a chimney, but be led above the roof if the places in which acetylene is used are built close to other buildings.

Munich (cont.)

The doors must open outwards. The rooms must only be lighted from the outside by well guarded lights, or by electric lamps with double bulbs. Switches and fuses must also be outside. These places are only to be entered with electric safety lamps.

5. The apparatus for generating and storing acetylene must be provided with safety appliances, which would prevent a pressure of more than half an atmosphere being reached.

Those parts of the engines, pipes, and other parts of the installation which come into contact with the acetylene must not consist of copper or have sharp edges. The use of alloys of copper with other metals is, however, permissible in fittings, cocks, and such apparatus in which the pressure does not exceed half an atmosphere.

Only qualified persons, who understand the construction of the apparatus, as well as the properties of the gas, and the process of generation, and who are thoroughly trustworthy, are allowed to look after and use the same.

6. The above regulations also apply to scientific institutes, except §§ 1 and 2.

If in such institutes acetylene is stored and used, it must be kept in steel vessels, made according to the rules for the conveyance of acetylene on the German railways, and not more than 5 kg. (11 lbs.) should be kept.

7. Any infringement of the above rules will be punishable by a fine of not more than 60 marks (£3), or the offenders committed for a period not exceeding 14 days.

MUNICH, *February 28th*, 1898.

THE MAGISTRATE OF THE CITY OF MUNICH,
Mayor von Borscht.

Nurnberg

NURNBERG.

Decree of the Magistrate of Nurnberg.

Notification.—Local police regulations for the manufacture and use of calcium carbide and acetylene for private and domestic purposes.

In accordance with § 366, No. 18, § 368, No. 8, of the Imperial Criminal Law, and Article 2, 94, 101, section 2, No. 2, 105, of the Bavarian Penal Code, the magistrate of the town of Nurnberg issues the following notification in consequence of a Royal Decree of the Government of Mittelfranken Home Office, of June 11th, 1898, No. 13,910, giving legal power to the undermentioned local police regulations from the day of their publication :—

§ 1. Any one desirous of making acetylene for private use, of

using it or calcium carbide, of erecting an acetylene generator —except table lamps or lamps for carriages or cycles—for temporary or permanent use, or proposing to deal in calcium carbide or apparatus for the generation of acetylene, must notify his intention to the magistrate and send in the plans and descriptions relating to it, and do everything imposed upon him by the magistrate in due time and without refusal, for the sake of safety and prevention of fire, and for the sake of health and cleanliness. **Nurnberg cont.)**

Such notification should be renewed if there is change of proprietorship.

Installations for decomposing calcium carbide under a pressure of more than one atmosphere, either for trade purposes or for acetylene gas, are forbidden.

The manufacture and use of calcium carbide and acetylene are subject to the rules of section 16, etc., of the Imperial Industrial Law.

Acetylene must not be kept or used in vessels under a pressure of more than half an atmosphere.

Apparatus for acetylene, with the exception of acetylene lamps, may only be worked after having been tested by the expert appointed for that purpose by the local police authority, and found to be in good order. Upon every apparatus a certificate must be fixed where it will be plainly visible, so that there can be no doubt as to its having been tested in accordance with the law.

Every one selling calcium carbide as well as acetylene apparatus must give a description of the calcium carbide apparatus or lamp.

§ 2. A license should be obtained from the magistrate before installations of acetylene gas light are worked.

§ 3. Calcium carbide and other carbides which are attacked by water must only be kept in hermetically sealed vessels made of sheet iron or stoneware, and stored in light, dry, and well ventilated places. A special license must be taken out for storing them in cellars.

The vessels must bear the legible inscription "Carbide, dangerous if not kept dry."

Quantities of more than 60 kg. (132 lbs.) must be stored in rooms specially built of non-combustible materials and which are water-tight. They must be at a distance of 10 metres (11 yards) from inhabited houses.

A special license has to be obtained from the police authorities for storing quantities of more than 300 kg. (660 lbs.).

§ 4. The grinding of carbide is forbidden to those not making a profession of the manufacture of acetylene.

Nurnberg (cont.)

§ 5. A special license must be obtained for manufacturing and storing acetylene in or under dwelling houses or workshops.

§ 6. The places in which acetylene is made must be light, fire-proof, and well ventilated, they must be heated only by steam or hot water pipes and must not be entered with a light, neither are they to be used for any other purposes; smoking is forbidden within the said premises.

The doors must open outwards.

§ 7. The apparatus for making and storing acetylene must be so made as to prevent the creation of a pressure of more than half an atmosphere either in the holder or the pipes.

Safety appliances for the prevention of high pressures arising in the apparatus must not be provided with cocks.

§ 8. Those parts of the apparatus which come into contact with the acetylene, as well as gasholders, pipes and similar fittings, must not be made of gold, silver, copper, mercury or any other material which may cause the formation of explosive compounds.

§ 9. The safety valves of the acetylene generator and the ventilating pipes of the rooms in which the generation of gas is carried on must not end in chimneys but be led up into the open air.

§ 10. Apparatus working with a quantity of more than 1 kg. (2·2 lbs.) at a time must be erected at a distance of 10 metres (11 yards) from inhabited houses.

In such cases gasholders must be in another room than the one in which the generating apparatus is placed, and be situated 10 metres from inhabited houses, which room should fulfil the requirements of § 6 and be used only for gas generation, and no persons, except those required for working the apparatus, should be allowed there. The gasholder may also be erected in the open air.

The generators, even though very small, should be so separated if the gasholders contain more than 350 litres.

§ 11. The safety apparatus must always be kept in proper working order.

Those persons who attend to and work the apparatus must be qualified for the task.

§ 12. No residue from the acetylene gas making process, or other fluids containing acetylene, may be thrown or led into the water main or the canals of the town. They must be taken to some place indicated by the magistrate. The spent lime should be put in vessels hermetically sealed and provided with a safety valve, and be taken to the specified place.

§ 13. The magistrate reserves the right to make more regula-

tions and to legislate for scientific purposes with regard to special circumstances.

THE MAGISTRATE, DR. V. SCHAK, W. S. BECKH.
No. 48,380, 1, Fischer.

WURTTENBERG.

Wurttenberg

Decree of the Royal Wurttenberg Home Office.

Be it hereby decreed in accordance with § 368, No. 8, Imperial Penal Code, and with reference to § 22 of the royal decree regarding fire inspection, December 21st, 1876—*Official Gazette*, p. 513, as follows,—

§ 1. Any one desirous of making and using acetylene must give notice thereof to the police authorities not later than the first time the gas generating apparatus is in use.

In places of more than 10,000 inhabitants such notice should be sent to the local police authority, in all others to the Chief Magistrate.

2. It is forbidden to generate or store acetylene in or under inhabited places, neither may it be stored in cellars. Rooms wherein gas is generated should be separated from dwelling-houses by a fireproof wall or an open space. The apparatus for generating and keeping acetylene may only be erected in places having a light roof, except when the apparatus is only small and the gasholder contains not more than ¼ cubic metre, the capacity of the room being at least 25 cubic metres.

3. The places in which acetylene is generated and stored must be light, large, and well ventilated, and be heated only by hot water or gas pipes, and must not be entered with a light. The doors must open outwards.

Neither the ventilating pipes of the room, nor of the generator, must end in a chimney, but must be led into the open air, so that they cannot possibly escape into other rooms.

4. The apparatus for the generation and storage of acetylene must be so made as to prevent the creation of a pressure of more than half an atmosphere.

5. No parts of the generating apparatus, holders, or pipes, may be made of copper.

6. Only qualified persons, understanding the construction and working of the apparatus, must be entrusted with the same.

7. Calcium and other carbides in quantities of more than 10 kg. (22 lbs.) may only be kept in dry, light, and well ventilated rooms. Their storage is forbidden in cellars. The vessels must bear the inscription "Carbide, dangerous if not kept dry."

8. The vessels in which liquefied acetylene is to be kept must be painted white, and bear the inscription "Liquefied acety-

Wurttenberg (cont.)

lene, inflammable," besides giving the net weight and capacity in litres. They must also have been tested under a pressure of 250 atmospheres.

9. In filling cylinders, the proportion must not exceed 1 kg. of acetylene to 3 litres capacity.

10. The cylinders for condensed acetylene must be marked with the inscription "Acetylene, dangerous," besides giving the highest pressure allowed. They must have been tested under a pressure twice as great as the one allowed.

11. The bottles filled with liquefied or condensed acetylene must be protected from the sun's rays and the heat from stoves.

12. Liquefied or condensed acetylene must only be put in bottles of which no parts consist of copper or its alloys.

13. Those who at the publication of this decree already have acetylene gas generating apparatus, must notify this within four weeks to the police authorities § 1, 2, when they will be allowed the term of one year from the date of the publication of this decree to comply with the rules of § 2 and of the first part of § 3.

14. The rules of § 1–3 and § 13 do not apply to portable acetylene lamps, or those the burner of which is connected directly with the generating apparatus.

The above rules do not apply to:—

(*a*) Such installations for making acetylene for which, according to § 16 of the General Industrial Law, a special license has to be obtained.

(*b*) Scientific Government Institutes, in so far as they make and use acetylene for the purpose of teaching and study.

STUTTGART, *September* 30*th*, 1898.

W. S. PISCHEK.

Baden

BADEN.

Decree relating to the manufacture and use of acetylene.

With the exception of § 14, *which is here omitted, the decree for Baden, dated from Carlsruhe, January* 8*th*, 1898, *corresponds word for word with the regulations for the manufacture and use of acetylene for private and domestic purposes already quoted as being in force in Prussia.*

Hessen Darmstadt

HESSEN DARMSTADT.

Decree relating to the manufacture and use of acetylene for private purposes.

In consequence of Art. 290 of the Police Regulations, as well as § 2 of the Law of October 30th, 1851, relating to the installa-

tion and working of gasworks, and the position of gasometers, be it hereby decreed as follows:— **Hesse-Darmstadt (cont.)**

The decree, with the addition of a notification to the effect that the regulations come into force on the date of their issue, February 22*nd*, 1898, *is word for word the same as respecting the manufacture and use of acetylene for private and domestic purposes in Prussia.*

OLDENBURG.

Oldenberg

Publication of the Home Office *re* the manufacture and use of acetylene for private purposes.

OLDENBURG, *February* 7*th*, 1898.

In virtue of Act 9, § 6, of the Law of December 5th, 1868, on the organisation of a Home Office and some subordinate Departments, be it hereby decreed with the authority of the Government of the Duchy of Oldenburg:—

The Oldenburg decree is identical with the Prussian one already quoted for the manufacture and use of acetylene for private and domestic use, to which is added a notification that the regulations come into force on the day of their issue, February 7*th*, 1898.

SAXE-WEIMAR.

Saxe-Weimar

Laws relating to the manufacture, storage, and use of acetylene for private purposes.

Considering the danger connected with the manufacture, storage and use of acetylene, and in virtue of § 1, No. 2, of the Law of January 7th, 1854, page 17 of the *Official Gazette*, be it hereby decreed as follows:—

This decree is also without exception, word for word, the same as that of Prussia, so need not be quoted. It bears the date January 14*th*, 1898.

COBURG GOTHA.

Coburg Gotha

Laws relating to the manufacture, storage, and use of acetylene for private purposes, January 17, 1898.

By order of His Royal Highness, be it hereby decreed as follows:—

This decree, with the omission of parts A *and* B *of* § 12, *and the addition of a notification as to the date on which the regulations come into force* (*January* 17*th*, 1898), *is identical with that of Prussia.*

Saxe-Meiningen

SAXE-MEININGEN

Decree relating to the manufacture and use of acetylene, from the Ducal Minister, Department for Interior Affairs, March 29th, 1898.

In consideration of the danger connected with the manufacture and use of acetylene, which of late has become more frequent, we find sufficient reason to make the following regulations :—

Word for word the same as the original Prussian decree.

Anhalt

ANHALT.

Police Regulations relating to the manufacture and use of acetylene for private purposes.

In virtue of § 23 of the Law for the Police, July 1st, 1864, No. 31 of the collection of the Laws of Anhalt, be it hereby decreed as follows :—

Identical with the Prussian decree, dated from Anhalt, February 10th, 1898.

Altenburg

ALTENBURG.

Decree of the Ducal Government Home Office, relating to the manufacture and use of acetylene for private purposes, January 26th, 1898.

By the Ducal Home Office, be it hereby decreed for the manufacture and use of acetylene for private purposes throughout the whole of the Duchy, as follows :—

This decree, dated from Altenburg, January 26th, 1898, *is identical with the original Prussian decree, except for the following note which has been added at the end of the Regulations*:—

In reference to the above Police Regulations, be it hereby made known to the public that installations for making acetylene gas, in so far as they are worked on factory lines, are considered to be "chemical manufactures," as designated in § 16 of the Imperial Industrial Law, and are therefore subject to the rules given therein.

Liquefied acetylene, being an explosive material which can be used for explosions, is considered to be "explosive material" in the sense of the Law of June 9th, 1884, against criminal use of explosive materials, causing thereby danger to the public.

Schwarzburg-Rudolstadt

SCHWARZBURG-RUDOLSTADT.

Police Regulations relating to the manufacture and use of acetylene for private purposes.

In virtue of § 3 of the Law of December 6th, 1892, giving the penalties for infringements of the Police Regulations, be it hereby decreed for the whole of the kingdom, as follows :—

Here follows a copy of the Prussian decree, dated from Schwarzburg-Rudolstadt, January 17th, 1898.

Schwarzburg-Sonderhausen

SCHWARZBURG-SONDERHAUSEN.

Ministerial decree relating to the manufacture and use of acetylene for private purposes.

By order of His Royal Highness, dated March 29th, 1854, Collection of Laws, page 134, be it hereby decreed *re* the manufacture and use of acetylene in our kingdom, as follows :—

The Prussian decree is used verbatim, dated from Schwarzburg-Sonderhausen, January 22nd, 1898.

Schaumburg-Lippe

SCHAUMBURG-LIPPE.

Police regulations for the manufacture and use of acetylene for private purposes.

In virtue of § 5 of the Police Law of May 22nd, 1892, be it hereby decreed that the following are the Police Regulations for the whole kingdom :—

Another copy of the Prussian decree, coming into force March 2nd, 1898.

Lippe-Detmold

LIPPE-DETMOLD.

Regulations for the manufacture and use of acetylene for private purposes.

With the Royal consent the following police regulations are hereby published :—

Another copy of the Prussian decree, dated from Lippe-Detmold, February 12th, 1898.

Reuss-Schleiz-Gera-Lohenstein-Ebersdorf

REUSS-SCHLEIZ-GERA-LOHENSTEIN-EBERSDORF.

Ministerial decree for the manufacture and use of acetylene for private purposes, March 31st, 1898.

Here follows the Prussian decree, to which is added the following note :—

The above regulations, by which the ministerial decree of July 22nd on the same subject is annulled, *Official Gazette*, p. 257, come into force on the day of their publication, March 31st, 1898.

Hamburg

HAMBURG.

Referring to the publications of January 8th, 1897, *Official Gazette*, p. 29; April 2nd, 1898; *Official Gazette*, p. 265; and April 6th, 1898, *Official Gazette*, p. 327, notice is hereby given to the public that in order to prevent any danger, a license for storing calcium carbide and making acetylene gas for private purposes may only be obtained under the following conditions, unless any others be provided for special cases:—

I. Storage of calcium carbide.

1. Calcium carbide must only be kept in water-tight metal vessels, which are fireproof and kept in dry, light, and well ventilated rooms. Their storage in cellars is forbidden.

2. The vessels must bear the inscription, "Carbide, dangerous if not kept dry."

The storehouses must be built of non-combustible material, and must be separated from inhabited dwellings by a fireproof wall or an open space. The roofs of these places must be very light.

Combustible materials must not be stored in these houses.

3. They must be heated by steam or hot water pipes, and it is forbidden to enter them with a light, a lighted cigar, or anything of a similar character. If electric lamps with double bulbs are used they must be outside the storage rooms, as must also any switches or fuses.

The doors must open outwards and must be fireproof.

4. The above rules must be hung up in the storage rooms in such a position as to be easily seen.

II. Manufacture of acetylene for private purposes.

1. Acetylene must not be generated or kept, neither must calcium carbide be kept in or underneath, places in which people are living, nor in cellars. Such places must be separated from houses inhabited either permanently or for some period of the day or night only, by a fireproof wall or an open space.

2. These places must be built of non-combustible material, must be light, large, and well ventilated, and must be heated only by steam or hot water pipes. It is forbidden to enter them with a light, a lighted cigar, and anything of a similar description.

Artificial lights may only be used if well protected, lamps and electric incandescent lamps with double bulbs being placed outside the storage rooms, as are also the switches and fuses. The doors must open outwards and be fireproof, besides which the roofs must be light.

No other combustible material may be stored in these rooms.

The ventilating pipes of the rooms must not end in or near chimneys. **Hamburg (cont.)**

3. The apparatus for making and storing acetylene must be so made as to prevent the creation of a pressure greater than one and a tenth atmosphere in the apparatus, pipes, or gasholders (see § 3 of the publication dated January 8th, 1897; also April 2nd, 1898, and April 5th, 1898).

No part of the generating apparatus, gasholders, or pipes must consist of copper. For fittings and cocks, however, the use of copper alloy is permissible. Tubes may be used for connecting various parts of an apparatus.

4. The gas pipes must be laid by gasfitters, according to the regulations for gasfitters of 1879, and they must be gas-tight up to 35 cm. water pressure. A certificate thereof must be produced.

5. The calcium carbide must only be kept in water-tight and fireproof metal vessels.

The vessels must bear the inscription, "Carbide, dangerous if not kept dry."

The carbide must only be taken out of the vessels in such quantities as are required for immediate use.

6. The above regulations, as well as the rules for using and handling the apparatus, making and using calcium carbide, and also for the prevention of danger and explosions, etc., must be hung up in the workrooms so as to be plainly visible.

HAMBURG, *November 3rd*, 1898.

BREMEN.

Bremen

Regulations for the manufacture and use of acetylene for private purposes, January 9th, 1898.

The magistrates decree as follows:—

Here follows another repetition of the Prussian decree, to which are added the two following notes:—

15. The regulations of February 13th, 1897, for acetylene gas and calcium carbide are hereby cancelled.

Resolved at the meeting of the Senate of Bremen, held on January 7th, and published on the 9th, 1898.

LUBECK.

Lubeck

Regulations relating to the manufacture and use of acetylene for private purposes.

By an order of the Senate the Police Magistrate hereby gives notice:—

The first eleven paragraphs correspond to those of the Prussian decree, the three last being as follows:—

Lubeck (cont.)

12. It is forbidden to use portable acetylene gas lamps.

13. The above regulations do not apply to installations in factories for making acetylene, for which according to § 16 of the General Industrial Law, a special license is required.

14. Infringements of these regulations, unless thereby any heavier punishment be incurred under any other existing law, shall be punishable by a fine of not more than 60 marks (£3), and any one unable to pay such a fine will be committed accordingly.

LUBECK, *January* 18*th*, 1898.

HEAD OFFICE OF THE POLICE.

Alsace

ALSACE.

County Police Regulations.

In virtue of Art. 2, No. 9, of the third part of the decree of December 22nd, 1789, *re* the Provisional Meetings and the Meeting of the Administrative Corporation, and in virtue of § 3 of the law of 1803, of the Division of the Country and the Administration, I hereby decree the following :—

1. Any one desiring to erect an acetylene generating apparatus, except it be done for purposes of trade, when § 16 of the General Industrial Law has to be complied with, must give immediate notice thereof to the local police authorities.

2. Such installation may be worked only after it has been inspected by the Industrial Inspectors and a written permission has been obtained from the local police authorities.

STRASSBURG, *November* 3*rd*, 1897.

THE COUNTY MAGISTRATE
V. FREYBERG.

Austria

AUSTRIA.

Decree of July 19th, 1898, Z 3352.

The rules fixed by the decree of June 15th, 1897, Z 22112, are in future to be as follows :—

1. The gas pipes must have been tested for leakage as required by the gas regulations before use. Only iron and lead may be used for them. It is permissible, however, to employ gutta-percha tubes for connecting lamps which can be moved, for gas stoves, etc.; but there must be a cock to shut the gas off from the tube, there being no such cock at the lamp, gas stove, etc. Lead pipes must only be used where they cannot be damaged, and they must be fully exposed.

2. There must be permanent ventilation in the storage rooms for calcium carbide.

3. The residue left in the apparatus by the gas generation

Austria (cont.)

process, in which small quantities of water drop or fall on to the calcium carbide, may be thrown into the water closet after its volume has been increased five times unless there be a canal with running water close at hand. The residue from fixed house apparatus for lighting dwellings and smaller houses must only be thrown into the water closet after its volume has been increased ten times, unless, as in the former case, there be a canal with running water close at hand.

If there be no such canal with a sufficient flow of water, the residues from the apparatus must be thrown into a cesspool or disposed of in some harmless way.

In the case of residues from apparatus for lighting large buildings, factories, or blocks of buildings, also for towns and large villages, water-tight pits with covers to fit must be built. Their contents must be taken to an open tract of land, and can also be used for making mortar or lime. Residue of prepared calcium carbide, which has been used for making cartridges and which is not like sludge, being a dry, hard material, can be treated as dust.

4. The storage rooms in the basement must only be entered with a safety lamp.

5. Water must be run continually through the generating apparatus, and in exceptional cases a fresh supply of water may be introduced by filling it afterwards.

6. The water seal in the gasholder must be provided with a proportionate quantity of salt. For apparatus exposed to change of temperature the seal must be covered with oil or glycerine.

7. Every apparatus must be set out with an exact description of its parts and of the management and use thereof.

This description must be framed and glazed and put up in the room with the apparatus. It must also contain particulars for the information of the public about the use and properties of calcium carbide and acetylene, in order that attention may be drawn to the dangers connected with the handling thereof.

8. All lamps from which the gas is shut off by cocks must have been tested by a qualified person as to their freedom from leakage.

9. Calcium carbide must be kept in closed, soldered tin vessels in a dry place, with as much ventilation as possible. Only those who thoroughly understand calcium carbide and its treatment are allowed to enter these rooms.

10. It is forbidden either to make or use liquefied acetylene.

11. Acetylene must not be stored under a pressure of more than $1\frac{1}{2}$ atmospheres.

12. It is forbidden to heat acetylene to more than 100° C.

Austria (cont.)

13. The use of metals like copper and silver is forbidden, the acetylene combining with them to form explosive compounds.

14. It is forbidden to store any explosive materials either in the generating or storage rooms used for calcium carbide.

Switzerland, Appensell, a. R.

SWITZERLAND, CANTON APPENSELL, a. Rh.

Regulations for erecting and working apparatus for acetylene lighting.

In reference to and in order to execute the regulations given under i.—§§ 47 ff.—of the Insurance Law, the Government has decreed to-day, November 9th, 1897:—

1. Installations for lighting with acetylene, and for keeping calcium carbide, must only be erected or worked with the sanction of the Insurance Committee, and after notice thereof has been given to the local committee for fire inspection.

Applications for such a license must be in writing, and sent to the Insurance Committee with a description and plan of the place where the installation is to be erected, together with a description of the apparatus.

2. The use of liquefied acetylene, acetylene mixed with air, and portable lamps connected with generators, is forbidden.

3. The rooms in which calcium carbide is kept and acetylene made must be separated from each other; they must be so built that either can be shut off and must be fireproof. The walls and doors, at least, must be made with mortar or gypsum. They must be light, protected against the cold, and provided with good ventilation.

These rooms must not be used for other purposes, and must not be entered with a light, which must be indicated by a notice affixed to the entrance of the same so as to be clearly visible.

4. The stock of calcium carbide must not exceed 50 kg. (110 lbs.) except in special cases, when an authorisation from the President of the Insurance Committee is required. It must be kept in hermetically sealed and water-tight vessels.

5. The apparatus for generating and storing the gas must be built of sufficient strength for automatic regulation, and be provided with a manometer if designed for a higher pressure than that required to force the gas through the system of pipes and to produce a sufficient light.

The highest pressure allowed is six atmospheres.

6. The use of pure copper in the apparatus is forbidden.

7. Only reliable and qualified persons must use and attend to the apparatus.

Switzerland (cont.)

The apparatus must be cleaned and filled with carbide during the daytime only.

8. The license can be withdrawn at any time, and no damages paid if the holder thereof does not comply with these conditions, or if his neighbours lay claim to it on account of the danger arising from the working of such installations.

9. The Insurance Committee is entitled to send experts at any time to look over the installation, or to go and see it themselves.

10. Infringements of the above will be punishable according to the penal code.

11. These regulations come into force at once.

Basle.

Switzerland Basle

Regulations for the manufacture and use of acetylene gas.

The authorities of the Canton Basle, considering the danger of calcium carbide and acetylene, and supplementary to § 16 of the Law for Building Inspectors of March 22nd, 1882, and §§ 1 and 2 of the Law for Inflammable Materials and their Industry of May 8th, 1878, hereby decree the following regulations:—

1. For every installation and working apparatus either for making calcium carbide or for manufacturing and using acetylene gas, a license from the Building Inspector has to be obtained.

For this purpose a written application, drawn up in accordance with § 16 of the Law for Building Inspectors of March 22nd, 1882, must be sent in, in which a plan of the installation and system to be used must be carefully described.

It must be accompanied by—

(*a*) A plan giving the situation of the ground where the installation is to be erected, signed by the Recorder.

(*b*) Plans, *i.e.*, sketches and drawings, of the rooms and stories where the installation is to be erected. On the same a careful drawing of the apparatus, ventilation, etc., must be given.

(*c*) Drawings of such parts of the generating apparatus and gasholders as are deemed necessary, in virtue of § 6 of these regulations, and as regards their being subject to examination by building experts.

1. The gasholders will be subject to the Law for Boilers of March 20th, 1880.

2. Before giving a license, the Building Inspectors must make an inspection and get a report from the Fire Inspectors, members of the Fire Brigade Committee.

3. Each license is valid only for the application and plan

Switzerland
Basle (cont.)

given therein. If the building is transferred to other hands, the new proprietor must have the license transferred to him.

The license expires when another building is to be used for the same installation.

If, in consequence of erecting an installation by license, considerable nuisance should arise, the Building Inspectors are entitled to order that the necessary measures be taken and to see that they are executed or to withdraw the license entirely. The Government cannot be held responsible, however, for any claim for damages.

4. The use of liquefied acetylene is forbidden until further notice.

5. The use of portable lamps in connection with gas generators is forbidden.

6. Gasholders, in which the result of atmospheric pressure and cubic contents is more than one atmosphere, are subject to the Law for Boilers, 1880, § 20–§ 26 as regards their construction and inspection.

7. Amongst dwelling houses it is forbidden to store more than 50 kg. (110 lbs.) of calcium carbide, which must be kept in solid iron, air- and water-tight vessels.

Quantities of more than 50 kg. must be kept only in rooms adapted for such storage, such rooms not being situated in inhabited quarters.

8. The manufacture of acetylene must only take place in rooms which are fireproof, and in which there is plenty of daylight; they must be dry, easily accessible, and provided with good ventilation. The ventilator must be constructed to supply a continuous draught of fresh air, and the impure air must be led through large pipes of such height that no nuisance is caused thereby to the neighbourhood.

It is forbidden to enter these rooms with a light, and a notice to this effect must be put up at the entrance, where it will be clearly visible.

9. The pressure in the gas generating apparatus and the pipes must not exceed six atmospheres.

The apparatus must be provided with a manometer and governor, and the pressure regulated automatically.

10. It is forbidden to use copper in constructing the apparatus, copper alloy, however, being admissible.

11. Only such persons as are trustworthy, who understand the construction of the apparatus, and who know the properties of the gas, are allowed to attend to and use the apparatus.

12. On every apparatus there must be an inscription, which is clearly visible, forbidding people to touch the apparatus unless they understand its working.

Switzerland
Basle (cont.)

13. In giving a license the Building Inspectors are not responsible for any damages arising through the execution of the same or the working of the installation, the proprietor, or his representative, alone being held responsible.

14. Any infringement of these regulations, or of the instructions of the Building Inspector given in connection with the above, will be punished in virtue of §§ 114, 116, 118, and 120 of the Penal Police Law.

BASLE, *May* 11, 1898.

For the Government,
President, Dr. PAUL SPEISER.
Secretary, Dr. A. WACHERNAGEL.

Switzerland
Basle district

BASLE DISTRICT.

Regulations for the manufacture and use of acetylene.
September 27th, 1897.

The authorities of the Canton of Basle district, considering the manufacture and use of acetylene gas as having an explosive character, will only grant licenses if special precautions are taken, and decree hereby, in virtue of § 6 of the Fire Insurance Law of March 16th, 1868, and of § 67 and 84 of the General law of the Trade Industry of December 10th, 1855, the following regulations:—

1. A license must be taken out for storing calcium carbide, and for working acetylene gas apparatus and using this gas. It will be granted after an examination by an expert of the Financial Committee.

2. Calcium carbide must be stored and manufactured only in rooms which are fireproof, and lighted by daylight, and are also dry and well ventilated. It is forbidden to enter them with a light.

The quantity of calcium carbide kept in store must not exceed 50 kg. (110 lbs.).

3. Portable lamps with a gas generating chamber must not be used. It is also forbidden to use liquefied acetylene.

4. The pressure in the gas generating vessels and pipes must not exceed six atmospheres. The apparatus must be regulated automatically, and be provided with a manometer.

The use of pure copper in the construction of the apparatus is forbidden, but copper alloy may be used for the purpose.

5. Only such persons as understand the construction of the apparatus, and know the properties of the gas, should attend to or use the apparatus.

On every apparatus there must be a visible inscription for-

Switzerland
Basle district (cont.)

bidding people who do not understand the working thereof to touch it.

6. The Finance Committee must from time to time have all the existing installations inspected.

The experts are paid by the Fire Inspectors' Department of the Canton.

7. Infringements of these regulations are punishable with a fine of from 5 to 100 francs (£4), any one offending a second time against any regulation will be punished twice as heavily, the fine going to the Fire Inspectors' Department.

The rules of §§ 107, 115, and 168 of the Penal Code remain in force, and so does § 37 of the Fire Insurance Law.

8. If any installation has not been erected according to the above, an order for its removal can be granted, and, if required, such installation can be removed at the expense of the owner in a legal manner.

9. The above notice comes into force on the day of its publication in the *Official Gazette.*

Given on September 27th, 1897, at Liestal.

For the Government,

President, DR. STRAUMANN.
Secretary, KAUMULLER.

Switzerland
Bern

CANTON BERN.

Regulations for the manufacture and use of acetylene.
April 14th, 1897.

The Government of the Canton Bern, considering the danger arising from the careless manufacture of acetylene by persons either negligent or unfitted for the work, as well as the nuisance to the neighbourhood and the damage done to public health, in execution of § 2 and § 14, No. 2, letter *a*, and No. 3, letters *g* and *h*, of the Industrial Law of November 7th, 1849; and § 110, last sentence of the Fire Law of February, 1st, 1897; and for supplementing § 1, letter *b*, of the regulations of May 27th, 1859; in consequence of the proposition made by the Chief Committee of the Home Department, hereby decrees:—

1. For erecting an installation for the manufacture of acetylene for purposes of trade or private use, a notification must be made as required in §§ 24 ff. of the above mentioned Industrial Law, and a license approving the plan for building and erecting the installation must be obtained. It is forbidden to have any installation without such a license.

2. It is forbidden to use liquefied acetylene, unless permission be given at some future date.

3. There must be two separate rooms, one for storing the

carbide and one for making the acetylene; they must be fireproof, sufficiently lighted with daylight, dry, and well ventilated.

4. It is forbidden to use the rooms for other purposes, or to enter them with a light. The apparatus must be regulated automatically, and have a manometer attached to it should there be a pressure of more than two atmospheres in the vessels or pipes. The pressure must not exceed six atmospheres.

The use of portable acetylene gas lamps, having the gas generated in a chamber connected therewith, is forbidden.

6. It is forbidden to keep more than 50 kg. (110 lbs.) of calcium carbide in stock, and it must be stored in air- and water-tight vessels.

7. It is forbidden to use pure copper in the construction of the apparatus, copper alloy, however, being permissible.

8. The apparatus must be cleaned and filled with carbide and water in daylight only.

9. Only trustworthy persons, understanding the construction of the apparatus, and knowing the properties of the gas and carbide, should attend to and use the apparatus.

10. Every apparatus must bear an inscription, which should be clearly visible, forbidding persons to touch the machine unless having a right to do so.

11. These regulations do not apply to scientific Government Institutes, in so far as they use acetylene for the purposes of teaching and study.

12. Anyone infringing the above regulations will be subject to the penalty given in § 95 of the *Industrial Law* of November 7th, 1849.

13. The license can be cancelled at any time without notice if the holder should not fulfil the conditions attached thereto, or if any important claim be brought in for danger by the working of the installation, or nuisance to the neighbourhood.

14. The above regulations come into force at once. They must be recorded in the *Collection of Laws*.

Bern, *April 14th*, 1897.

Canton St. Gallen.

Publication of Police Regulations for the manufacture and use of acetylene.

As it has been found that efforts have been made to introduce acetylene light into the Canton of Gallen, and that, notwithstanding what is said in the prospectus of the Factories and Limited Liability Companies, acetylene is injurious to health and is inflammable; for both these reasons it is the imperative

Switzerland
St. Gallen
(cont.)

duty of the authorities to take proper measures for the prevention of accidents. The Government, taking as its basis the advice of experts, has given authority to the Department, reserving to itself rights of alteration in view of further experience to be obtained on this subject, to make the provisional regulations given below.

1. For the present it is forbidden to use compressed acetylene in steel or iron cylinders, or acetylene lamps, the gas of which is generated in a chamber connected with the lamp.

2. The material for making the gas, calcium carbide, must be stored in a closed dry room in hermetically sealed and water-tight vessels. It is forbidden to enter the store-room with a light.

3. The generator and gasholder must be erected in a place separated from the main building, and every such place must be well closed and ventilated.

4. It is forbidden to put the material for generating the gas into the apparatus by the aid of any artificial light.

5. The apparatus must only be used by trustworthy persons who understand its construction and know the properties of the gas, and the material used in its generation.

6. It is forbidden to use metallic copper in the construction of the apparatus—generators, gasholders, pipes, and burners.

7. Notice must be given to the Financial Department, through the local fire police authorities, before a new installation can be worked, and a license applied for at the said Department.

St. Gallen, *January 5th*, 1897.

The Financial Department,
Senator Keel.

Acetylene Gas.—In the publication of January 5th, 1897, *re* police regulations for the manufacture and use of acetylene gas—see *Official Gazette*, 1897, No. 1, s. II.—the use of compressed acetylene gas in metal or iron cylinders is forbidden until further notice. After reference to the applications sent in, however, we find sufficient reason to declare that the expression "compressed gas" comprises only such acetylene as has been condensed to liquefaction, and for which at least a pressure of 21·5 atmospheres is required if subsequently cooled down to 0° C. This rule should be clearer, and must therefore be changed as follows:—

"It is forbidden to use compressed liquefied acetylene gas."

St. Gallen, *January 25th*, 1897.

For the Financial Department,
Senator Keel.

Switzerland St. Gallen (cont.)

Police Regulations for storing calcium carbide for acetylene lighting.

In connection with our publication of January 5th and 25th, 1897, of police regulations for the manufacture and use of acetylene gas—*Official Gazette*, 1897, Vol. I., pages 11 and 74—we hereby decree, in accordance with the wishes of the Government, the following regulations for the storage of calcium carbide :—

1. A license must be obtained from the local fire police authorities for storing quantities of more than 100 kg. (220 lbs.) of calcium carbide.

2. It must be kept only in closed dry rooms, and in hermetically sealed and water-tight vessels.

3. Quantities of up to 500 kg. of calcium carbide must be stored in fireproof rooms built in compliance with the requirements of § 9 of the regulations for the Canton, *re* the traffic of petroleum and other inflammable liquids, of October 6th, 1893.—*Collection of Laws*, new set, Vol. VI., No. 74, page 406.

4. For storing larger quantities of calcium carbide a room must be built at a distance of at least 60 m.—66 yards—from the nearest building, and must be erected in compliance with the rules given in § 6 of the regulations mentioned above.

St. Gallen, *November 26th*, 1897.

For the Financial Department,
Senator Keel.

Switzerland Lucerne

Canton Lucerne.

Regulations for the manufacture and use of acetylene gas. September, 1898.

The Government of the Canton Lucerne, in reference to the report and proposition made by the Military and Police Departments, decrees :—

1. A license must be obtained from the Police Department for every installation erected for the manufacture and use of acetylene. Such a license is held to be in force only for the places for which it has been obtained. A license must also be obtained for installations already existing.

Applicants must pay the fee due for the license and the cost of the inspection.

2. The calcium carbide must be stored, and acetylene made, in detached fireproof rooms, which must be dry, well ventilated, and closed, besides being lighted by daylight.

3. The calcium carbide must be pure, and contain only the smallest quantities of calcium phosphide.

Switzerland
Lucerne
(cont.)

4. The stock of calcium carbide must not exceed 100 kg. (220 lbs.), and must be kept in hermetically sealed, water-tight vessels.

5. The use of portable acetylene lamps connected with a generating chamber is forbidden until further notice.

6. The use of liquefied acetylene, or acetylene mixed with air, is also forbidden until further notice if the air is mixed with the acetylene in the holder and not in the burners.

7. The pressure in the generator and pipes must not exceed six atmospheres. The apparatus must be regulated automatically and have a manometer attached.

8. It is forbidden to use pure copper for the construction of the apparatus, copper alloy, however, being permissible.

9. Only trustworthy persons, who understand the construction of the apparatus and the properties of the gas and the material for making it, must work or attend to the apparatus.

10. Each apparatus should bear a notice in some visible place forbidding any one not understanding the machine to touch it.

11. Infringements of these regulations will be punished according to the Penal Police Code.

12. These regulations come into force at once. The original copy must be placed in the Government Archives, and be published in the *Official Gazette* of the Canton, and printed in the Collection of Government Regulations.

LUCERNE, *September 9th*, 1898.

For the Government,
U. HEGI.
Clerk, M. SCHNYDER.

Switzerland
Neuchâtel

CANTON NEUCHÂTEL.

Original Translation. Decree *re* the use of acetylene gas, May 14th, 1897. The Cabinet of the Republic and the Canton Neuchâtel.

In consideration of the Regulations of April 6th, 1897, for the manufacture and use of acetylene gas, and the Resolutions of the International Conference at Bern of March 24th, for the consideration of measures for the prevention of, and protection against, danger; also the report handed in by the Deputy of the Department of Internal Affairs, and the special regulations mentioned above for the prevention of accidents incurred by the storage and careless treatment of the material used for the manufacture of the gas and the use of apparatus, the safety of which is not guaranteed, hereby decrees—

1. All persons about to have installations erected in their

workshops, stores, rooms, or any other places, must previously obtain a license from the Department of Internal Affairs. **Switzerland Neuchâtel (cont.)**

2. It is forbidden to use liquefied acetylene.

3. The use of portable acetylene lamps is also forbidden.

4. Only apparatus with a gasholder and an automatic regulator for the pressure arising in the generation of the gas are allowed.

5. The use of apparatus made of pure copper is forbidden.

6. The pressure arising in public installations, as well as in those of public halls, must not be greater than $1\frac{1}{2}$ atmospheres.

7. This pressure can be increased to six atmospheres in the case of industrial concerns.

8. Calcium carbide must be stored in detached rooms containing no gas pipes.

9. It is forbidden to store a larger quantity than 60 kg. (132 lbs.). The calcium carbide must be stored in tins containing not more than 20 kg. (44 lbs.), and their entire contents must be used.

10. A visible notice must be put up at the entrance of these storage or generating rooms, forbidding any unauthorised person to enter.

11. Only trustworthy persons who understand calcium carbide, the gas generating process and the apparatus, and have been taught the properties of the material to be treated, are to be entrusted with the apparatus.

12. Each infringement of the regulations will be punished with a fine of from 20 to 100 francs (£4), and should anybody be killed or seriously injured, or a fire be caused, Art. 256, 299, 300, and 321 of the Penal Code will apply thereto.

13. The carrying out of these regulations belongs to the Home Department. They will be published in the *Official Gazette* and added to the *Collection of Laws.*

NEUCHÂTEL, *May* 14*th*, 1897.

For the Government,
President, CLERK.
Secretary, FR. SOGUEL.

CANTON NIEDERWALDEN. **Switzerland Nieder-walden**

Regulations for the use and manufacture of acetylene :—

1. For every installation for storing calcium carbide, as well as for each working apparatus for the generation and use of acetylene, a license must be obtained from the Government, which will be granted only after inspection by an expert.

2. Until further notice it is forbidden to use liquefied acetylene.

Switzerland
Nieder-
walden
(cont.)

3. It is forbidden to use portable lamps which are connected with a gas generating chamber.

4. Calcium carbide must be stored in places other than those in which acetylene is made; these places must be fireproof, lighted by daylight, dry, and well ventilated. It is forbidden to enter them with a light.

5. The stock of carbide must not be larger than 50 kg. (110 lbs.).

6. The pressure in the generator and pipes must not exceed six atmospheres. The apparatus must be automatically regulated and provided with a pressure gauge.

7. Pure copper must not be used in the construction of the apparatus, copper alloy, however, being permissible.

8. Only trustworthy persons who understand the construction and properties of the gas, and the generating material, are to be entrusted with the apparatus.

9. On every apparatus a visible notice must be fixed forbidding any one not understanding the machine to touch it.

10. Infringements of these regulations—apart from any civil consequences—will be punished with a fine of from 5 to 100 francs (£4), and a stop can be put to the working of the apparatus until the above regulations have been complied with.

11. The carrying out of these regulations, which come into force at once, lies in the hands of the Government.

Resolved by the House.

STANS, *July 26th*, 1897. For the House,

F. BUSINGER. F. NIDERBERGER, Clerk.

Switzerland
Schaff-
hausen

CANTON SCHAFFHAUSEN

Regulations for the manufacture and use of acetylene.
November 11th, 1898

1. For every installation for storing calcium carbide, as well as for each working apparatus for the manufacture and use of acetylene, a license must be obtained from the Government, which will be granted only after investigation by an expert.

The applications for such licenses must be sent to the Town Council, accompanied by a plan of the construction, a map of the place, and a description of the apparatus, as well as the report of a previous examination by the police inspector.

2. The use of liquefied acetylene, of acetylene mixed with air, and of portable lamps with a generating chamber attached to them, is forbidden.

3. The calcium carbide must not be kept in the rooms in which acetylene is generated. These rooms must be separated

Switzerland Schaffhausen (cont.)

from each other, be well closed, fireproof, lighted by daylight, dry, protected against cold, and well ventilated.

The use of these rooms for any other purposes is forbidden, and they must not be entered with a light, which fact must be indicated by a notice fixed at the entrance in such a way as to be plainly visible.

4. The stock of calcium carbide must be kept in hermetically sealed water-tight vessels, and must not exceed 100 kg. (220 lbs.), except in special cases, when a license has to be obtained from the Town Council.

5. The apparatus for storing and generating the gas must be sufficiently strong, automatically regulated, and provided with a pressure gauge if made for a higher pressure than that required to distribute the gas through the system of pipes and to give a certain light. The pressure must not exceed six atmospheres.

6. It is forbidden to use pure copper for the construction of the apparatus.

7. Only trustworthy persons, who understand the construction of the apparatus, are to be entrusted with it.

8. On every apparatus a visible notice must be fixed, forbidding anyone who does not understand the apparatus to touch it.

9. Every license is held to be in force only for the locality mentioned in the application.

10. The installation may be inspected at any time, and the proprietor thereof is bound to obey the instructions given by the officials appointed for such inspections.

11. Scientific institutes using acetylene for purposes of teaching or study are exempted from some of the above regulations.

12. Infringements of these regulations, unless coming under the Penal Law, will be punishable with a fine of from 5 to 100 francs, or the withdrawal of the license.

13. These regulations come into force at once.

SCHAFFHAUSEN, *November* 11*th*, 1898.

President, J. HELLER.
Clerk, H. WOLF.

Switzerland Tessin

CANTON TESSIN.

Regulations for the manufacture and use of acetylene.
March 15th, 1898.

The Government of the Republic and the Canton Tessin decrees —

In reference to the law of May 5th, 1875, for inflammable and

Switzerland
Tessin
(cont.)

explosive materials, and the Public Health Law, which regard the manufacture of acetylene as a dangerous industry, when those employed in the manufacture thereof are not controlled by certain regulations, or lack experience, therefore according to the proposition made by the directors of the Hygienic Department—

1. It is forbidden to erect in this Canton any installation for generating acetylene either for trading purposes or for the private use of the owner unless an application has been sent in in accordance with § 3 of the law of May 5th, 1875, and a license obtained beforehand direct from the Government.

Such a license will only be granted after the Director of the Hygienic Laboratory of the Canton has investigated the matter and sent in his report thereon.

2. The application must be sent to the Mayor of the city or town in which the installation is to be erected.

The Mayor shall ask the Director of the Laboratory to attend to the matter and to give a declaration that such examination has taken place.

The rooms must be examined as well as the apparatus.

The cost thereof must be borne by the owner of the apparatus.

3. It is forbidden to use compressed acetylene in iron or steel cylinders, portable lamps having a generating chamber attached to them, and lighting apparatus in which the acetylene is mixed with air.

The apparatus for generating and storing the acetylene must be strong, provided with automatic regulation, and, should the pressure in the pipes and holders exceed two atmospheres, be furnished with a pressure gauge.

The pressure must not exceed six atmospheres.

4. It is forbidden to use pure copper for constructing the apparatus, copper alloy, however, being permissible.

5. The rooms in which acetylene is manufactured must be separated from those in which the acetylene is stored. They must have large windows and be fireproof.

These rooms must not be used for any other purposes, nor be entered with a light or matches.

6. It is forbidden to store more than 100 kg. (220 lbs.) of calcium carbide, and it must be kept in hermetically-sealed vessels.

7. The apparatus must be cleansed and filled in broad daylight.

8. Only experienced persons are to be entrusted with installations for generating acetylene gas.

A notice forbidding any other person to touch the apparatus must be fixed thereon.

These installations are erected under the supervision of the Director of the Hygienic Laboratory of the Canton.

Switzerland
Tessin
(cont.)

9. The above regulations do not apply to apparatus in scientific institutes for teaching purposes.

10. Infringements of the above regulations will be punishable according to §§ 13, 14, 15, and 16 of the Law of May 5th, 1875.

11. The license for an installation for generating acetylene can be withdrawn if the conditions notified therein are not complied with, or should weighty objections be raised against it.

12. The above decree shall be printed in the *Record of Laws*, and come into force at once.

The Government,
President, Curti.
Secretary, Casella.

Bellinsona, *March* 15*th*, 1898.

Notice relating to the special license for the installation of apparatus for generating acetylene gas.

The Directors of the Public Health Department of the Republic and the Canton Tessin to the Hon. Magistrate.

In reference to the regulations given by the Government on March 15th, 1898, for the manufacture and use of acetylene, the above-mentioned Directors consider it necessary to request the Hon. Magistrates to observe the regulations comprised in the above more strictly.

They are especially reminded of their duty to prevent any installation of apparatus for generating acetylene being erected and used without a Government license having been applied for, or the rooms in which the apparatus is erected not being built in accordance with the regulations.

As it is further possible that in some cases apparatus for generating acetylene have been erected without complying with the conditions enacted in the regulations, the Hon. Magistrates are requested to prosecute inquiries as to whether all these apparatus have Government licenses, and to take the necessary steps in accordance with the Law with regard to such persons as have not obtained them.

We would also remind the officials that it is their duty to make frequent inspections in order to protect the Public Health, these installations according to § 8 of the Regulations of March 15th, 1898, being subject to the supervision of the Director of the Hygienic Laboratory.

Casella.

Bellinzona, *December* 14*th*, 1899.

Switzerland
Unterwalden

Bill to be laid before the Council of the Canton for approval of same, January 14th, 1899.

CANTON UNTERWALDEN OB DEM WALD.

Regulations for the manufacture and use of acetylene gas.

The Government of the Canton Unterwalden ob dem Wald, considering the dangerous character of calcium carbide and acetylene gas, decrees hereby, supplementary to the Fire Police Regulations of November 15th, 1852, and of April 23rd, 1879:—

1. For every installation for storing calcium carbide, and apparatus for generating and using acetylene, a license must be obtained from the Government.

This license is held to be in force only in the place for which it has been obtained.

A license must also be obtained for existing installations.

For this purpose a written application must be sent to the Police Department, giving an exact description of the proposed installation and the system to be used therein.

This application must be accompanied by maps and a plan of the place in which the installation is to be erected, as well as sketches of the details of the apparatus, and the ventilating arrangements.

2. Every application for erecting an installation for acetylene must be examined and attested by an expert with regard to its construction.

The cost of such examination and certificate must be borne by the applicant.

3. Every new tenant of a place in which there is an acetylene installation must have the license transferred to him, and made out in his name.

Should the tenant desire to use the same installation in another place, a fresh license must be obtained.

If, in consequence of erecting an installation by license, nuisance of any kind is complained of, the Government is authorised to order its removal, and even to entirely withdraw the license without any liability as to damages.

4. The use of portable lamps connected with a gas-generating chamber, as well as of liquefied acetylene, is forbidden until further notice.

5. Gasholders in which the pressure in atmospheres and capacity in square metres is more than 1 kg. (2·2 lbs.) are subject to the regulations of March 20th, 1880, for boilers—§ 20 to § 26 of the Regulations of the Council of the Swiss Union—as regards their construction and inspection.

6. Calcium carbide must not be stored, nor acetylene gener-

ated, in or under rooms in which people are living, nor in cellars, but only in fireproof rooms separated from each other and lighted only by daylight, dry, well ventilated, and covered by a light roof. Switzerland Unter-walden (cont.)

It is forbidden to enter them with a light, which fact must be announced by a notice at the entrance.

7. The stock of calcium carbide in places near to other buildings must not be larger than 50 kg. (110 lbs.).

It must be kept in iron, hermetically-sealed, and watertight vessels.

Quantities of more than 50 kg. must only be stored in proper places erected far from other buildings.

8. The pressure in the generating vessels and pipes must not exceed six atmospheres.

The apparatus must be provided with a pressure gauge giving the maximum, and the pressure must be automatically regulated so as to prevent the occurrence of a pressure greater than that stated as the maximum.

9. It is forbidden to use pure copper for the construction of the apparatus, copper alloy, however, being permissible.

10. Only reliable persons, who understand the construction of the apparatus and properties of the gas and raw material, are to be entrusted therewith.

11. To every apparatus a visible notice must be fixed, forbidding any one who does not understand the apparatus to touch it.

12. In granting a license the Government does not take any responsibility for damages arising through the erection or working of an installation, the owner, or his representative, being held solely responsible.

13. The local authorities of each town have to see to the carrying out of these regulations, and for this purpose they must order the frequent examination of the installations.

14. Infringements of these regulations, or of the special decrees given by the Government in connection with the above, will be punishable according to §§ 25 and 122 of the Police Penal Code.

15. These regulations come into force at once. They will be published in the *Official Gazette* and added to the *Collection of Laws*.

Canton Wallis.

Switzerland Wallis

Regulations of August 20th, 1897, for the manufacture, sale, and use of acetylene.

On the proposition of the Judicial and Police Department, the Government of the Canton of Wallis decrees :—

Switzerland
Wallis
(cont.)

1. Every one desirous of erecting an installation must take out a license at the Judicial and Police Departments.

2. The use of liquefied acetylene is forbidden.

3. The rooms used for storing calcium carbide and the manufacture of acetylene must be fire-proof, sufficiently lighted, dry, and well ventilated.

4. The apparatus for generating and storing the gas must be so constructed as to avoid a pressure of more than two atmospheres in the generator, gasholders, and pipes. The pressure can be raised to ten atmospheres for trading purposes.

The apparatus must be provided with an automatically-regulated pressure gauge.

5. The rooms in which acetylene is manufactured for trading purposes must be at a distance of 200 metres (220 yards) from other buildings.

6. Calcium carbide kept in stock for the same purpose must be kept in perfectly dry rooms.

7. It is forbidden to use pure copper in the construction of the apparatus.

8. The apparatus for acetylene light, whether used temporarily or permanently, must be so constructed that the pressure therein cannot become greater than during the process of manufacture—one to two atmospheres.

9. Infringements of these regulations will be punished with a fine of 10 to 100 francs, to be fixed by the Judicial and Police Department; whilst the right of appeal to the Government is reserved, and all damages have to be paid.

Resolved at the Council at Sion, August 20th, 1897, to be published in the communities of the Canton on Sunday, September 5th.

President, DUCREY.
Lord Chancellor, CH. ROTEN.

Switzerland
Zug

CANTON ZUG.

Regulations for the manufacture and use of acetylene.

The Government of the Canton Zug hereby decrees, supplementary to the rules of the Fire Police Regulations of July 7th, 1862, and in compliance with the Conference held for all the Cantons on March 24th, 1897:—

1. For every installation for storing calcium carbide, and for working the apparatus for making and using acetylene, the permission of the Government, given on the report of the expert who investigated the matter, must be obtained.

2. The Government reserves the right to make exceptions according to circumstances; otherwise the rules of the Con-

ference of all the Cantons of March 24th, 1897, held at Bern, are here applicable.

Switzerland
Zug (cont.)

The rules read as follows:—

It is forbidden to use liquefied acetylene until further notice. It is also forbidden to use portable lamps with gas-generating chambers attached.

Calcium carbide must be stored in different rooms to those in which acetylene is generated; all such rooms to be fireproof, sufficiently lighted by daylight, dry and well ventilated.

The stock of calcium carbide must not exceed 50 kg. (110 lbs.).

The pressure in the generator and pipes must not exceed six atmospheres. The apparatus must have an automatic governor and pressure gauge.

It is forbidden to use copper in the construction of the apparatus, copper alloy, however, being permissible.

Only reliable persons, who understand the construction of the apparatus and the properties of the gas and material, are allowed to use and attend to the apparatus.

On every apparatus a notice must be fixed, forbidding any other person to touch it.

3. Infringements of the above regulations will be punished with a fine of not more than 100 francs (£4), unless it be a penal case.

4. Notice of any infringement must be sent in writing to the local police station. The police must send a report of an inquiry to the Government, who will then order a magistrate to attend to the matter.

5. These regulations come into force on the day of their publication in the *Official Gazette.*

Zug, *May* 19*th*, 1897. A. Weber.

For the Government—Clerk, A. Keyser.

Canton Zurich.

Switzerland
Zurich

Regulations for the installation and working of acetylene apparatus, November 18th, 1897.

1. For the installation and working of acetylene apparatus, and the installation for storing calcium carbide, permission must be obtained by application to the local police, when a written license will be given by permission of the Directors of the Police of the Canton. It depends upon the result of an examination by experts whether or no a license is granted.

The application for such licenses must be in writing and

Switzerland
Zurich
(cont.)

sent to the local police authorities, accompanied by a description and plan of the place where the apparatus is to be erected. The authorities after examining such applications, and making all remarks thereon that they may think fit, must send them to the Directors of the Police.

2. It is forbidden to use liquefied acetylene, or acetylene mixed with air; also portable lamps with gas-generation chambers attached.

3. The rooms for storing calcium carbide must be separated from those in which acetylene is generated. All these rooms must be well closed, fireproof, sufficiently lighted by daylight, dry, protected from cold, and well ventilated.

It is forbidden to use these rooms for other purposes or to enter them with a light, a visible notice whereof must be fixed at the entrance.

4. Any stock of calcium carbide must be stored in hermetically sealed and water-tight vessels, and, except under special circumstances, it must not exceed 100 kg. (220 lbs.).

5. The apparatus for generating and storing the gas must be sufficiently strong and automatically regulated, should be made for a higher pressure than that required for distributing the gas through the system of pipes, and must also be provided with a pressure gauge.

The pressure must not exceed six atmospheres.

6. It is forbidden to use pure copper for constructing the apparatus.

7. Only trustworthy and qualified persons are to be entrusted with the use and care of the apparatus.

8. Every license is held to be in force only for the place mentioned therein.

9. Licensed acetylene gas installations are subject to inspections, which can be made at any time, and the owners thereof are bound to carry out the instructions given by the officials.

10. Scientific institutes using acetylene gas for the purpose of teaching and study are exempted from some of the above regulations.

11. Infringements of these regulations, unless any section of the Penal Code is applicable, will be punishable by the withdrawal of the license, and a fine, according to the Police Law.

12. These publications come into force after they have been published in the *Official Gazette.*

ZURICH, *November*, 1897.

For the Government—Clerk, STUSSI.

FRENCH REGULATIONS.

France

PREFECTURE OF POLICE.

Use of Acetylene

Instructions relating to the use, for lighting purposes, oi acetylene gas, and precautions to be taken in its employment.

1. In order that the use of acetylene may present no danger, it is necessary that the burner allow no gas to escape. A cock shall be fitted at the extremity of the piping, or beyond the region affected by the manufacture of the acetylene. The end of the pipe line shall be stopped by a cap and closed with a cock. At the point of distribution a pressure regulator, or any other arrangement to prevent abrupt variations of the pressure, would offer advantages from the point of view of public safety.

2. All places in which acetylene is used must be carefully ventilated, even when the gas is not in immediate use; that is to say, each room must be provided with openings communicating directly with the open air, by which the gas may escape in case of leakage or non-combustion. These openings, two in number, should be placed as far as possible opposite each other, one immediately below the ceiling, the other level with the floor.

All cupboards and confined spaces containing burners, or intersected by pipes, should be ventilated by two openings of at least half a decimetre square, these openings to be placed, one in the upper, the other in the lower portion of the space to be ventilated, and in cases where direct communication with the open air is impossible the measurement of these openings to be enlarged to a decimetre square.

Without these precautions the gas is likely to accumulate in such confined spaces and occasion serious accidents.

3. All supply pipes and other apparatus used in the distribution and consumption of the gas to be visible, with the exception of such parts as traverse ceilings, floors, walls, wainscots, partitions, cupboards, or other empty spaces. Every time the pipes are thus hidden from view they shall be enveloped in a continuous shield either of iron, brass, or copper, this shield to be open at both ends and extend at least a centimetre beyond the face of the wall, partition, or flooring, etc., in which it is embedded. The internal diameter of the shield shall be at least a centimetre greater than the pipe which it envelops.

France (cont.)

Should a pipe follow a sharp bend in the wall, partition, ceiling, or floor, the shield shall be completed by a cap assuring the ventilation of the space between the pipe and its shield.

All supply and distribution pipes shall be made in a high quality of metal other than zinc, and be perfectly adjusted.

Should the acetylene be produced or consumed under a pressure of above 1·50 m. of water, the use of copper or its alloys in any part of the pipes shall be prohibited.

4. Every burner shall be furnished with a tap, the plug of which shall be arranged in such a way as to prevent its being pushed out, even with a violent effort. A wedge shall be so placed as to arrest the plug when the tap is turned off.

These taps shall be from time to time well greased, in order to facilitate the service and avoid oxidation. In lighting, the principal tap must first be turned, and then a light applied to each burner the moment its own tap is turned, in order to avoid any escape of the gas.

In putting out the gas, first each burner shall be turned off, then the principal tap, which shall always be placed at the point of entrance of the gas into the premises to be lighted by it. In closing this cock when no more gas is required one is always safe from accident.

5. Should a smell of gas indicate an escape, all doors and windows shall at once be opened and the taps closed.

Never use a light when trying to locate a leakage.

If either by accident or carelessness an escape shall have become lighted, close the main cock in order to extinguish it. In case of accident the Commissioner of Police shall be immediately notified thereof.

6. It sometimes happens that, owing to the sloping position of the pipes, water accumulates at their base and prevents for a moment the passage of the gas, during which time the flame is extinguished. The gas then escapes unburnt and may cause an explosion. To prevent this danger every such place shall be provided with an arrangement for removing the water.

Drawn up and adopted on the report of M. H. Beinel, at the meeting held on December 24th, 1897.

Secretary, Drujon.
President, Dr. Bouchardat.

The manufacture of gaseous acetylene for private use. General conditions of authorisation.

Private installations

1. The apparatus used in the manufacture of the gas shall be placed in a well-ventilated building specially designed for the purpose, the door of which shall be kept locked.

All apparatus for exhibition in shop windows shall be enclosed in glass cases, ventilated top and bottom, and closed on the side next the shop. **France (cont.)**

2. All operations connected with the charging and emptying of the apparatus shall be conducted by daylight, and no one shall be allowed to enter the building containing the apparatus with a light.

3. Indiarubber tubing between the generator, holder, or supply pipes is absolutely prohibited.

4. In no portion of the apparatus shall the water pressure exceed 1·50 metres.

5. All necessary precautions shall be taken to prevent the freezing of the water in the apparatus during the winter.

6. The holder shall be fitted with a safety tube communicating with the open air.

7. The products yielded by the decomposition of the carbide shall be thrown into an open vessel, and submitted to ten times their own volume of water, before being emptied into the sewer.

Any residue required for further use shall be kept under water for several days.

8. The calcium carbide shall be placed in an hermetically-sealed tin and kept in a dry place.

9. In the apparatus and use of acetylene gas the instructions of the Hygienic Council of December 24th, 1897, shall be complied with.

The first French Regulations now in force.

The principal conditions for manufacturing acetylene gas :—

1. The apparatus must never be erected in a cellar.

2. It must be put up in the open, or in a well-ventilated room, separated from places in which explosive material is made. These places must have windows opening on to a large space and not on to any small court.

3. It is forbidden to throw the liquid residue, or any portion left over from the calcium carbide, down a drain until it has been mixed with ten times its own volume of water.

4. It is forbidden to use indiarubber tubes to connect the generator with the gasholder, or the latter with the pipes.

5. The pressure in the apparatus—generator, gasholders, and pipes—must nowhere exceed 50 cm. of water, *i.e.* 0·05 kg. real pressure, to be measured with a water manometer.

PARIS, *March 5th*, 1897.

Belgium

BELGIUM.

Royal decree supplementary to the regulations for the manufacture and use of acetylene.

Leopold II., King of Belgium, considering that the manufacture of acetylene, the storage of liquefied or compressed gas, the depôts for calcium carbide and other carbides which in combination with water produce acetylene, are not entered on the list of dangerous and unhealthy materials (see the Royal decree of January 29th, 1863, and December 27th, 1863. and the list of dangerous and unhealthy materials which was added to the Royal decree of May 31st, 1887): nor the report of the General Office for the Transactions of Work, whose duty it is to guard against dangerous, unhealthy, or badly arranged matters: nor the Report of the High Council for the Public Health: nor that of the Royal University in Belgium *re* the nuisance and danger arising from the generation of acetylene for the workmen and the public safety: therefore, in reference to the dangers caused by the use of liquefied or compressed acetylene, and by the storage of calcium and other carbides, which, when mixed with water form explosive mixtures, and the nuisance and dangers arising therefrom, we have resolved, in accordance with the proposition made by our Ministers of Industry and Labour, to issue the following decree:—

1. The factories wherein acetylene is manufactured, the stores of liquefied acetylene, or those in which acetylene compressed at more than 1½ atmospheres pressure is kept, the stores of calcium and other carbides, are to be considered as dangerous as well as injurious to the public health.

They will be put on the list of the Royal decree of May 31st, 1887, under the following headings:—

Description.	*Class.*
Non-compressed acetylene, or acetylene compressed at more than 1½ atmospheres pressure, the manufacture thereof, except such gas as is generated in portable lamps.	1 A. Substances and residues having a disagreeable smell; the danger of poisoning people; the danger of explosion by the setting on fire of a substance mixed with air; danger of fire.
Liquefied acetylene, or acetylene compressed at more than 1½ atmospheres pressure, the manufacture thereof.	1 A. Substances and residues having a disagreeable smell; the danger of poisoning; the danger of explosion.
Liquefied acetylene, or acetylene compressed at more than 1½ atmospheres, stores thereof.	1 A. The danger of explosion.

Belgium (cont.)

Description.	*Class.*
Calcium, or other carbides which, when combined with water, produce acetylene, of at least 50 kg. in stock.	1 B. Disagreeable smell; danger of explosion.

2. Our Minister for Industry and Labour is ordered to execute these regulations.

Given at OSTEND, *August* 15*th*, 1898.

For His Majesty KING LEOPOLD.
Minister for Industry and Labour, A. NYSSENS.

NORWAY.

Norway

Law for the storage and sale of calcium carbide, and also for the manufacture and use of acetylene gas.

1. Calcium carbide must be stored or sold only in accordance with the regulations given for the safety of the public by Royal Decree, or by order of His Majesty. The manufacture and use of acetylene is subject to the same regulations.

2. Liquefied acetylene can only be manufactured, stored, sold, and used after a special license has been obtained from the King or an official representing him.

3. Infringements of this law, or the regulations given in accordance therewith, if no heavier punishment be incurred under any already existing law, are punishable with a fine. The punishment will be fixed in accordance with the rules for police court cases.

4. This law comes into force at once.

Given at STOCKHOLM, *December* 10*th*, 1898.

OSCAR.
O. BLEHR.
LEHMANN.

Regulations for the storage and sale of calcium carbide and the use of acetylene gas, etc., given by Royal Decree, December 10th, 1898.

1. Calcium carbide must be stored only in strong watertight metal vessels, and in dry, light, and well-ventilated rooms. No vessel must contain more than 50 kg. It is forbidden to store larger quantities than 10 kg. in dwelling houses or cellars. The vessels must bear a clear inscription, "Calcium Carbide."

2. Calcium carbide must not be stored or sold until notice thereof has been given to the police.

3. Quantities of more than 1 kg. of calcium carbide must not be stored in vessels other than those mentioned above.

4. It is forbidden to erect or work an installation for making

Norway (cont.)

acetylene before a license has been obtained from the police. The installation can only be renewed by permission of the police. Before this is given the police are entitled to demand the report of an expert *re* the installation.

5. The gas must be generated in a place which is separated from any other building by a wall built according to the regulations given by law (see the law for the building trade in the towns of this country, except Christiana, Bergen, and Drontheim, July 27th, 1896, § 49), or by an open space of at least 5 sq. metres. The generating apparatus must be erected in a room with a lightly-built roof.

Small apparatus, if not charged with more than 10 kg. of calcium carbide, may be erected in dwelling places by permission of the police.

6. Rooms in which acetylene is made must be light, large, and well ventilated. Within such rooms only electric lamps may be used and no stove may be employed. The ventilating pipes of the rooms and of the generator must not pass through nor end in a chimney; the pipes of the generator must be led to the top of the roof of the building. This is not necessary, however, for the small apparatus mentioned in § 5.

7. The apparatus for generating and storing acetylene must be so constructed that the pressure shall not exceed one atmosphere.

8. No part of the generating apparatus, gasholders, or pipes may consist of copper.

9. Portable acetylene lamps, and those the burner of which is connected directly with the generating apparatus, are forbidden.

10. These regulations come into force at once.

Denmark
Copenhagen

DENMARK.

Resolution of the Council.

The Magistrate of Copenhagen hereby publishes the following decree, in reference to the publication by the Judicial Department of May 28th, 1897, which declares that the installation of acetylene gas works and similar factories now in the course of construction, together with the systems thereof, are subject to such regulations as the Magistrate of Copenhagen deems necessary for the prevention of danger from explosions and damage by fire :—

1. Before an installation for the manufacture of acetylene is erected, drawings and two descriptions of it must be sent to the Magistrate, and an assurance must be obtained that there is no objection to the execution thereof according to the drawings sent in, or in such manner as they have been altered at the request of the Magistrate.

Denmark (cont.)

In giving such a declaration, it will be taken into consideration what the building in which the installation is to be erected is used for; whether these buildings, although they are not to be let, are being used by a small or a large number of people, or whether they are close to such buildings.

It is forbidden to erect an acetylene installation in private houses. The rooms where the gas is generated or stored, or calcium carbide is stored, must be light and well ventilated, and must not be directly connected with dwelling places, *i.e.* places in which people stay the night. This rule does not apply to rooms protected by night watchmen, or in which work is carried on during the night.

2. A written notice must be sent to the Director of the Lighting Department before an installation is erected, and after the above-mentioned declaration has been obtained.

The testing and trial of the different parts of the installation, and the material to be used therein, as well as the pressure test, will be made under his direction after the installation is completed. Such materials as are considered not strong enough to last must be replaced by those of better quality. The necessary connections must be fixed and arrangements made for attaching pumps and manometer, so that the apparatus can be examined at any time without much delay.

3. The installation having once been erected cannot be altered, nor may the pipes be renewed until the Director of the Lighting Department has received a notice thereof that the trial required may be made.

The permission of the Magistrate must also be obtained if the works are to be enlarged or extended in any way.

4. The Director or Inspectors of the Lighting Department are allowed to enter the works at any time to ascertain that everything is in proper order. Any apparatus not in order will be stopped.

Once a year, or more often if deemed necessary, a pressure test must be applied.

5. As a mixture of air and acetylene is very explosive, the greatest care must be taken in using the gas. Only such persons as understand it thoroughly must generate and use it. Children and persons under 18 years of age must not assist in any work.

6. Any necessary cleaning must be done during the daytime, and care must be taken that during this period there is no fire or light in the rooms. As sometimes there is a danger of poisoning, two men at least must be employed in cleaning the apparatus. When the generators are cleaned, the residues must be thrown into a special holder and be mixed with ten times

Denmark (cont.)

their own volume of water before being thrown away or poured down a drain.

7. All the apparatus, pipes, etc., must be kept clean, all taps not required to be open must be turned off, and all joints and packings of the pipes must be tight, any defects being repaired at once. The ventilator must be tested daily to ensure its being in working order. As often as necessary it must be taken to pieces and lubricated with graphite.

In the case of an escape of gas no naked light must be used, but a safety lamp of an approved pattern must be kept ready in an adjoining room.

8. If the apparatus has not been used for 48 hours, the gas must be allowed to escape from the holder into the open air, and the acetylene may only be used after the holder has been filled again. The same rule applies after the apparatus has been cleaned, when it is filled with fresh calcium carbide or when newly erected, and some time must elapse before the gas is used.

9. Before leaving the work rooms the attendant must look round carefully to see that all taps are turned off properly and that everything is safe.

It is forbidden to smoke in rooms where acetylene gas is generated.

10. If acetylene is under a pressure of more than 12 inches of water, the holder must previously have been tested under a pressure five times as great as that under which the acetylene is used.

A washer must be inserted between the gasholder and the pipes, and the latter, which must be gastight under a pressure of 5 feet, must be provided with a safety valve constructed so as to call attention when the pressure reaches 12 inches of water. A special pipe leading to the open air must provide an outlet for the gas at a place where no danger of explosion can arise therefrom.

11. Copper must not be used for any part of the apparatus with which acetylene comes in contact. It is forbidden to connect the lamps and pipes with indiarubber tubes or tubes of similar material.

12. Calcium carbide must only be stored in watertight vessels and kept in dry places.

13. Liquefied acetylene and portable acetylene generators, including those lamps in which the gas is generated, must only be used in the open air. This rule also applies to the filling and cleaning of apparatus. On the whole the same precautions must be taken as in the case of acetylene gas works.

An exception to these rules may be made if the acetylene is used for scientific purposes by persons who it may be taken for

granted are fully qualified to know the danger they run in the use of such apparatus.

14. Any one refusing to comply with the above rules, the Director of the Lighting Department is entitled to stop the working of the installation, and an action will be brought against such persons according to § 40 of the law of May 25th, 1868, for the Fire Engineers at Copenhagen.

15. All expenses arising from the testing of installations and the inspection of the same, etc., must be paid by the proprietor as per statement approved of by the Magistrate.

16. A copy of these regulations must be put up in the works.

17. The laboratories and similar scientific institutions of the Government are exempted from these regulations.

18. The Magistrate reserves the right of altering or adding to these regulations if such be deemed necessary.

Signed by the Burgomaster and given under the seal of the town,

OLLGAARD MOLLER.

COPENHAGEN, *July* 25*th*, 1897.

On February 22nd, 1896, the Royal Danish Judicial Department passed the following resolution :—

Notification of additional Regulations to § 23 of the Public Health Regulations for Copenhagen, as approved by the Judicial Department.

In conformity with the Law of March 28th, 1868, on " Alterations of the Law with regard to the present condition of Public Health Regulations of January 12th, 1858," we hereby confirm the Additional Regulations to § 23 of the Public Health Regulations for Copenhagen, sanctioned by the Judicial Department, July 15th, 1886.

With the exception of the pipes of the gas works of the town, it is forbidden to erect installations or lay pipes in dwelling houses without the permission of the Public Health Committee, unless that part of the house where the installation is to be erected, or the pipes are to be laid, is separated by a solid fireproof wall, in which even iron doors are forbidden, from the inhabited part.

Dwelling houses are considered as such when people sleep in them at night. This rule does not apply to buildings protected by night watchmen, or those in which work is carried on during the night.

Roumania

ROUMANIA.

We have resolved and hereby decree—

1. Calcium carbide stores and factories for the manufacture of acetylene must be regarded as industrial establishments of the third class, and may only be built on the outskirts of a town or village and be separated from any neighbouring farm.

2. In densely-populated quarters in small villages calcium carbide may only be stored in quantities of not more than 15 kg. in solid iron hermetically-sealed vessels, which are kept in well-ventilated and lighted rooms.

3. For every installation of acetylene it is necessary to apply in writing for the permission of the Burgomaster of a town and the Prefect of a village, such application being accompanied by a map of the situation of the house and a plan of the apparatus and the ventilating system. The Burgomaster or Prefect will ask the Local Committee for Public Health for their approval of the application and plans, and give notice to the Minister of every license which has been granted.

4. For the removal of an installation a new license must be obtained in the manner indicated above.

5. If in a house with such an installation any danger should arise to the health of the inhabitants, the local authorities can withdraw the license.

6. It is forbidden to use liquefied acetylene.

7. It is also forbidden to use portable lamps to which generating chambers are attached.

8. The pressure in the gas apparatus must not exceed 3 to 5 atmospheres.

9. The apparatus must be provided with a manometer, and the pressure must be automatically regulated.

10. It is forbidden to use copper in the construction of the apparatus.

11. Only such persons as understand the apparatus are allowed to use and attend to it.

12. To every apparatus a visible notice must be fixed, forbidding any one who does not understand the machine to touch it.

13. Acetylene gas apparatus must be kept only in light, dry, well-ventilated fire-proof rooms. It is forbidden to enter these rooms with a light.

14. Our Home Secretary will see that these regulations are carried out.

Given at Pelesch Castle, July 16, 1897.

CAROL.

Home Secretary—M. PHEREKYDE.

Russia and Finland.

Russia and Finland

In Russia and Finland no regulations have at present been made, the Chief of Police at Lodz alone having drawn up some regulations.

Italy.

Italy

The Government has been engaged for some months in drawing up regulations, but they have not as yet been published.

Turkey.

Turkey

There are no regulations in Turkey.

Spain.

Spain

Except the Articles of some Fire Insurance Companies, there are no regulations for acetylene.

Sweden.

Sweden

No regulations have as yet been made. The Articles of the Fire Insurance Companies give rules for the use of acetylene.

Denmark.

Denmark other than Copenhagen

No regulations have been given up to the present either by the Police or the Government. The authorities do not approve of acetylene, and much depends upon the Mayor of the town.

Portugal.

Portugal

No regulations have as yet been made for the manufacture and use of acetylene.

Greece.

Greece

At present there are no special regulations for the use of acetylene and calcium carbide.

Hungary.

Hungary

There are no laws or police regulations for acetylene lighting, but drafts are being prepared.

The Netherlands.

Netherlands

Neither the Government nor the Town Councils have made any regulations. The manufacture of acetylene is subject to the so-called "Hindrance Law of the Town," and thus a license must be obtained from the Town Council. The Fire Insurance Companies do not allow the use of acetylene lighting in factories.

Luxemburg.

Luxemburg

The Government will soon publish regulations for the use of acetylene. For the time being, however, acetylene plant may be erected anywhere outside dwelling places.

ACETYLENE

Regulations for the Prevention of Accidents drawn up by the German Society of Chemical Industry, for the Manufacture, Use, and Liquefaction of Acetylene.

A. Regulations for Employers and Managers.

Regulations for employers and works managers

1. Acetylene must be manufactured in buildings other than those in which it is condensed, should the pressure be as high as 8 atmospheres. Otherwise the building must be separated from other houses.

2. The rooms in which acetylene gas is made, condensed, or liquefied must be light and well ventilated; they must only be heated by steam or hot water pipes, and the doors must open outwards.

3. The rooms for the generation, condensation, and liquefaction of acetylene must be lighted only by safety lamps placed outside these rooms. In case of emergency it is permitted to enter these rooms with safety lamps which have been inspected just before being used.

Trade regulations

4. Carbide must be stored in well-closed vessels to protect it against damp, and only as much as is wanted for immediate use must be taken out of them. The vessels must be stored in dry, well-ventilated rooms.

5. In grinding carbide, precautions must be taken to prevent any dust being formed. During the operation the men must be provided with respirators and spectacles.

6. The gasholder must be erected in the open, or in a well-ventilated room separated from that in which the gas is generated.

7. A water manometer must be attached to the gasholder, by which the pressure is visibly registered.

8. A good washer must be put between the generator and holder, by which impurities — phosphuretted hydrogen, sulphuretted hydrogen, ammonia, etc.—will be removed.

9. Acetylene must not be made by gradually adding water to the calcium carbide, but by gradually adding the calcium carbide to the water. The quantity of water must always be largely in excess of the quantity of calcium carbide.

10. The condensation of acetylene at a pressure of more than 10 atmospheres must be carried out in a cold room.

11. The condenser must be disconnected directly the acetylene is sufficiently compressed.

12. The vessels used for transporting the liquefied acetylene must be painted white and labelled; they must have been tested under a pressure of 250 atmospheres.

These vessels must not be filled in a proportion of more than 1 kg. acetylene to 3 litres capacity, the regulations of the

German Railway Companies forbidding the traffic of vessels otherwise filled.

The weight before and after filling must be carefully noted.

13. The vessels filled with liquefied acetylene must be protected from heat.

14. No vessels or parts of the apparatus which come into contact with liquefied acetylene may consist of copper or its alloys. No ventilators or any parts of the apparatus which come into contact with the acetylene may have sharp edges.

B. Regulations for Workmen.

Regulations for workmen

15. It is forbidden to enter the rooms in which acetylene is made, condensed, or liquefied, with a light, or to strike a match, or to use any lighting material whatever.

Safety lamps must always be examined before they are used. It is forbidden to open the lamps in these rooms.

16. When the carbide is ground, measures must be taken to prevent the formation of dust. The operators must use the respirators and spectacles provided for them.

17. It is forbidden to add water to calcium carbide, and it may be thrown into water only in such small quantities as always to have a large excess of water.

Trade regulations

18. In condensing and liquefying acetylene, care must be taken that there is no rise in the temperature.

19. The condenser must be disconnected directly the acetylene has been liquefied.

20. Only such vessels must be used for compressed acetylene as are indicated above.

21. In filling the vessels attention must be paid to the fact that they are not filled in a larger proportion than 1 kg. of acetylene to 3 litres capacity.

22. The weight of the vessels must be carefully taken before and after filling.

23. The filled vessels must be carefully protected against the sun's rays and against other sources of heat.

24. The vessels must be opened so that the acetylene only escapes gradually.

Fire Insurance regulations

Germany

FIRE INSURANCE REGULATIONS.

Germany.

Regulations of the German private Fire Insurance Companies for the prevention of accidents.

(*a*) For districts which have police regulations.

An insurance policy will not be granted unless the following conditions are complied with, as well as those of the police regulations:—

1. The gasholder must be provided with an apparatus by means of which the after-generation of the gas can escape as soon as the holder is filled.

2. The gasholder and generator must not in any case be erected in outhouses or stables unless they are separated from the adjoining places by a solid fireproof wall. The excess of gas mentioned in §1 must be led into the open air.

3. The rooms in which the apparatus is erected must not be used for storing combustible material; they must be kept locked, and no one must be allowed to enter unless they understand the apparatus. Smoking must not be allowed therein.

4. The manufacture, storage, and use of liquefied, compressed acetylene is forbidden.

(*b*) For districts which have no police regulations.

1. The gasholder must be provided with an apparatus by means of which the after-generation of the gas may escape as soon as the holder is full.

2. The generator and gasholder must in no case be erected in outhouses or stables, unless they are separated from the adjoining places by a solid fireproof wall. The excess of gas mentioned in §1 must be led into the open air.

3. The room in which the apparatus is erected must not be used for storing combustible materials. It must be kept locked, and no one must be allowed to enter unless they understand the apparatus. Smoking is not allowed therein.

4. The manufacture, storage, and use of liquefied, compressed acetylene is forbidden.

5. Acetylene must not be generated or stored in or underneath places which are inhabited, nor must it be kept in cellars. The room in which acetylene is generated must be separated from dwelling places by a fireproof wall or an open space. The generator must be erected only under a lightly-built roof.

Fire Insurance (cont.)

6. These rooms must be light, large, and well ventilated, and heated only with steam or hot water. The door must open outwards.

The ventilating pipes of the rooms and generator must not end in a chimney, but be led out above the roof.

7. The apparatus for generating and storing acetylene must be so made as to prevent the formation of more than one atmosphere pressure therein.

8. No parts of the generating apparatus, gasholders, or pipes may consist of copper.

9. Quantities of more than 10 kg. must only be kept in water-tight vessels, and be stored in dry, light, and well-ventilated rooms.

Switzerland.

Switzerland

Special regulations of the Bâle Insurance Company for the prevention of damage by fire through the installation and use of apparatus for generating acetylene.

1. In places in which a license must be obtained from the local authorities for erecting the apparatus for generating acetylene gas, application must be made for the same; and besides the rules entailed thereby the following have also to be complied with:—

2. It is forbidden to manufacture, store, or use liquefied, compressed acetylene.

3. Portable acetylene lamps must not be used.

4. The generator and gasholder must be erected in an empty room, which must be lighted by daylight, dry, protected against frost, and well ventilated. With the exception of electric lights, the use of any artificial illuminant is forbidden.

5. The calcium carbide must be kept in tightly-closed metal vessels, and in a dry room, which is separated from that in which the generating apparatus is kept. The stock must not exceed 100 kg.

6. The pressure in the apparatus must not exceed 1·1 atmospheres.

7. The gasholder must be provided with an apparatus by means of which the surplus gas generated may escape into the open air directly the holder is full.

8. When the lights are turned out, the tap between the gasholder and pipes must be turned off.

9. Any residues of calcium carbide from the gas must be taken out of the generator only when dry, and must be kept in the same way as calcium carbide.

10. Only trustworthy persons, understanding the apparatus

Fire Insurance (cont.)

and the properties of the gas and the materials used in its manufacture, must look after and attend thereto.

11. To every apparatus a visible notice must be fixed, forbidding any other person to touch it.

France

France.

Fire Insurance Regulations of the Syndicate of the French Fire Insurance Companies.

I. *Acetylene light installations.*

A. Open spaces lighted by acetylene, with generating apparatus and store for calcium carbide erected in a separate place. Dated March 31st, 1897.

The following regulations have been made for acetylene lighting on the resolutions of the Syndicate, October 5th and December 7th, 1896, and January 11th, 1897.

For acetylene lighting, except liquefied acetylene, no extra premium will be charged when the generating apparatus—generator and gasholder — and the stock of carbide are put outside the insured building, or the building in which the insured objects are.

The danger of gas explosions can be insured against with the same extra premium as in the case of coal gas—Tariff of simple dangers in factories and theatres—but besides this an extra premium of 0·05 per 1,000 francs must be charged for dwelling houses, owing to the danger of such houses, regardless of the danger to those who rent the houses and to the neighbours close at hand.

B. As soon as the apparatus, generator, and gasholder have been taken into the insured buildings, or the buildings in which objects are insured, the danger is thereby increased, and the insured parties will be obliged to give a written notice besides paying the extra premium at once.

For insurance against the danger of acetylene explosion, an extra premium must be paid as above. To either kinds of insurance the following rules apply:—

1. The apparatus, generator, and gasholder must be erected in a well-ventilated room, lighted by daylight. They must not be put up in cellars or basements, nor in badly-ventilated rooms.

2. Calcium carbide must always be stored in watertight metal vessels.

3. Liquefied acetylene must never be used.

4. The following clause must be added to the policies:—

This insurance policy does not make the Company liable for damages caused by fire through an explosion caused by non-com-

pliance with the rules given by the authorities, or by the use of portable or fixed lamps in the rooms with attached generators.

No charge will be made for the use of portable lamps, except those that are filled with liquefied acetylene.

Coal gas and acetylene may only be used together after the above extra premium has been paid.

The regulations for open places also apply to acetylene lighting as being dangerous.

II. *Calcium carbide.* May 31st, 1897.

Calcium carbide kept in iron, steel, or other metal vessels will be regarded as a dangerous material, and be classed under the Simple Dangers, page 26 of the Tariff.

This decree modifies but does not cancel the decree of December 14th, 1896, No. 1169, which relates to the general stores and public stores, and forbids the storage of calcium carbide amongst other materials. That decree remains in force.

Belgium.

Belgium

Regulations of the Committee of the Foreign Fire Insurance Companies in Belgium. Original translation.

In accordance with the general police regulations, acetylene lighting cannot be installed in rooms insured against fire without previous notice. This notice must be sent to the Fire Insurance Company.

After the notice has been approved, insurance against fire can be obtained after the acetylene installation has been erected, subject to the following conditions:—

1. It is forbidden to use liquefied acetylene or portable acetylene lamps.

2. The generator or gasholder must only be put up in a place separated from the insured part, or the place where the insured objects are.

The calcium carbide with which the apparatus is filled must be kept in well-closed, water-tight vessels, which must not be stored in the insured rooms.

3. An extra premium of 0·30 per cent. will be charged for any objects, furniture, or immovables which have been insured against fire.

The police will not interfere if such extra premium has been paid, and if the above conditions are fulfilled.

The damage, even without a fire, which can be caused by an acetylene explosion, can also be insured against in the same policy by payment of a second extra premium of 30 per cent.

Fire Insurance Sweden

Sweden.

Swedish Tariff Union. Conditions for insuring acetylene factories in which carbide, usually called calcium carbide, is the raw material, and for places in which this raw material is stored.

1. No insurance of acetylene installations, or places in which they are used, will be accepted unless they have been examined by an expert. To this end, sketches, plans, and an accurate description of the apparatus, and of the manner in which it is to be worked, must be sent to the office of the Tariff Union.

No model of any installation will be acknowledged unless it has been examined and watched for a period of thirty days by an expert.

2. The installation, which consists of a generator and gasholder, must be of solid construction and gastight. Copper must not be used.

3. The installation must be properly erected, either in a separate room, or in a light, well-ventilated one, approved of by the Tariff Union.

4. The capacity of an installation erected in a dwelling house must not exceed three cubic metres, nor must a larger quantity of carbide then 15 kg. of carbide be used therein.

5. Installations must be filled or cleaned only by daylight, or by a light external to the room.

6. The rooms must be so ventilated that the escaping gas is carried out into the open. No chimney must be used for such ventilation.

7. When the generator is being filled, the pipes leading to the gasholder must be shut off.

8. The calcium carbide used in the installation must be as pure as possible, and the acetylene generated must not contain more than 0·01 per cent. of phosphuretted hydrogen. The carbide must evolve at least 250 litres of gas per kg.

9. The carbide must be kept in strong iron vessels, with overlapping covers, or in wooden boxes lined with metal, soldered down.

Such vessels and boxes must bear the inscription "Carbide," in order to indicate to the public the dangerous character of their contents if not kept dry.

10. In the building or room in which the installation is erected there must not be kept more carbide than is required to fill the apparatus, except such quantity as is already in the apparatus.

11. For storing the carbide the regulations for the storing of inflammable oil, first class, and the restrictions as to the quantity

which may be stored, apply; 1 kg. of carbide being considered equivalent to 1 litre of inflammable liquids.

12. Arrangements must be made in a room or building for the necessary water supply.

13. Every part, both internal and external, of the installation must be easily accessible.

14. Generators, gasholders, and water tanks must not be separated by a wall, unless they are in separate rooms. They must be connected by large pipes, with as few bends as possible, and must not be connected by indiarubber tubes. These pipes must have a cock for withdrawal of any condensed liquid.

15. The highest pressure in any part of the installation must not exceed 100 cm. water pressure.

16. If the flow of gas between the gasholder and generator is automatically regulated, they must be separated from each other by a certain distance.

17. The generator must be so constructed as to hold ten times more water than carbide. The cross section of the holder must be twice as great as the cross section of the carbide at the point where the latter comes into contact with the water. Where the connections between the generator and holder are fixed, these proportions must be doubled.

18. The cross section of the vessels, baskets, or nets in which the carbide is lowered into the water must not exceed 15 cm. diameter.

19. The gas in the holder must be separated from the water by a layer of at least 5 mm. of pure fat oil—not mineral oil. If the room is not sufficiently protected against frost, the water must be boiled and then saturated with salt.

20. Gas pipes must not be made of copper, copper alloy, or indiarubber; but ventilators, cocks, and burners may be made of copper alloy.

21. The generator and holder must be provided with safety valves which work automatically as soon as the pressure therein exceeds 100 cm. water.

22. The residue of the apparatus must be thrown into a vessel filled with water, and be stirred from time to time before being emptied.

23. Only trustworthy persons who understand the work must be entrusted with it.

24. Acetylene apparatus are considered as vessels of inflammable liquid of the first class: thus the total volume of gas in the generator and holder is taken as the basis for working out the charge.

25. It is forbidden to manufacture, store, or use liquefied acetylene.

Fire Insurance Spain

SPAIN.

Regulations for the Spanish Fire Insurance Companies.

Instructions with regard to acetylene:—

For acetylene gas lighting, except when obtained from liquefied acetylene, no extra premium is charged if the apparatus, generator and gasholder, and the stock of carbide are outside the insured building, or the building in which the objects insured are.

If the acetylene apparatus, generator and gasholder, are within the insured buildings, or within the buildings which contain insured objects, the person insured must give notice at once, and the premium will be increased as follows:—

5	Centesimo for	dwelling houses.
35	,, ,,	furniture and similar goods.
30	,, ,,	stores and workshops.
30	,, ,,	factories and factory workshops, and halls for public entertainments.

These extra premiums are only added on account of the danger of fire. For insuring against acetylene explosions another similar premium will be charged.

To this class of insurance the following conditions apply:—

1. The generator and gasholder must stand in a light, well-ventilated room, in which there must be openings covered with iron gauze. The apparatus must not be erected in a cellar or basement.

2. The stock of calcium carbide must be kept in metal vessels and be protected against damp.

3. It is forbidden to use liquefied acetylene.

4. The following clause must appear in the policy: "The person insured binds himself to pay all damages in the event of an accident, and to comply in every respect with the regulations made by the authorities for the consumption of acetylene. The use of portable lights is forbidden in the rooms in which the acetylene apparatus is erected. In default thereof the policy is void."

Calcium carbide factories—

Working with coke or coal, the stock of carbide at a distance of 10 metres from the factory		4 per cent.	2/4
Working with charcoal, and having the stock of carbide at 10 metres from the factory		5 per cent.	2/11
Working with any coal, and having the stock at a distance of 10 metres		6 per cent.	3/6
The stock of carbide at a distance of 10 metres from the factory	buildings	3 per cent.	1/9
	carbide store	5 per cent.	2/11

LEGAL ENACTMENTS

Fire Insurance

America

AMERICA (*See page* 716).

Austria and Hungary

AUSTRIA.

The rules of the Fire Insurance Companies resemble those of the Union of the German Private Insurance Companies, being based upon the same principles, and requiring a strict obedience to the police regulations.

One of the principal Austrian Insurance Companies in Vienna charges a premium of 5 per cent. for insurance against danger arising from acetylene. In HUNGARY it is the same.

Russia and Finland

RUSSIA.

The Insurance Companies in Russia and Finland do not charge anything for acetylene installations.

England

ENGLAND.

Generally the English Insurance Companies are acting upon the same principles as the German Companies. Some of them charge no extra premium, and others have endeavoured, but without success, to raise their premium in the case of the acetylene apparatus being erected in the insured building.

Netherlands

THE NETHERLANDS.

The Insurance Companies generally object strongly to the introduction of acetylene, and do not allow its use in factories.

Denmark

DENMARK.

The Insurance Companies generally make it a condition that the building in which the apparatus is erected shall be a detached one, and at a distance of at least 10 metres from other buildings. They do not demand an extra premium, but refuse to insure the building in which the apparatus is.

Traffic regulations

GERMAN TRAFFIC REGULATIONS.

Regulations for the conveyance of calcium carbide and liquefied acetylene by Railway Companies.

Calcium Carbide.

B. No. XLIX of the traffic regulations for the Railway Companies of Germany.

Traffic by Railway. Calcium carbide must be packed in airtight iron vessels. No other material may be packed in the same vessels. Postal delivery. According to §11 of the postal regulations of December 18th, 1874, the following are not allowed to be sent by post: "Objects or substances, the delivery of which is dangerous when rubbed, pressed, or by the accidental admission of air into the parcel, easily inflammable materials, and objectionable liquids.

It is forbidden to send calcium carbide and acetylene by post. (Decision of the Imperial Postal Department.)

Transport by Sea. The steamship companies do not convey calcium carbide in the passenger boats, and only a limited quantity in the cargo vessels. They require it to be packed in strong tins put in wooden boxes.

River Transport. Companies for conveying goods by river steamers require calcium carbide to be packed in various ways. Some accept calcium carbide packed in strong tins, others require it to be packed in tin-lined boxes strong enough for the voyage, whilst other Companies will not take it at all.

Liquefied Acetylene.

The rules for the transport of liquefied acetylene are nearly the same for all the Railway Companies as for liquid carbonic acid; the duty on liquefied acetylene is almost without exception the same as for carbonic acid in all the different states of the German Empire. As the trade of liquefied acetylene is not important, and as it is too insignificant for the acetylene industry, only some of the German rules for the transport thereof are given below.

Section B No. 44 of the traffic regulations for the Railway Companies of Germany.

Traffic regulations (cont.)

The rules given hereafter for liquefied carbonic acid apply also to liquefied acetylene, but the following are also added :—

To be added to § 1. No part of the gasholder must consist of copper or copper alloy. The valve must be of steel.

To be added to § 2. The holders must have been tested under a pressure of 250 atmospheres, and they must not be filled in a proportion larger than 1 kg. of liquid acetylene to 3 litres capacity.

XLIV. Liquefied gases—carbonic acid, nitrogen, ammonia,* chlorine, sulphuric anhydride,* and phosgene—are subject to the following rules:—

(The gases marked * are subject to rules which are omitted as not applying to acetylene.)

1. These chemicals may only be sent out in cast iron or steel bottles. The vessels must (*a*) be tested every three years for carbonic acid, nitrogen, and ammonia under the pressure given in § 2, and the vessels must stand the test without any alteration of form and be guaranteed perfectly gastight; (*b*) bear the inscription officially prescribed, giving the weight of the vessel when empty, and also with the cap fitted on ; also the weight of the quantity which may be put in the vessel expressed in kg. according to § 2, and also the date of the last test. This inscription must be put on in such a place that it can easily be seen.

C. 1. The valve caps must be of the same metal as the vessel, and be fixed strongly to the valve.

2. The vessels must be provided with some arrangement for preventing unauthorised persons opening the valve.

3. If the vessels are packed tightly in cases, it is not necessary to put caps over the valve.

4. The highest pressure to be used for testing the vessels, and the largest quantities allowed to be put in a vessel are, for carbonic acid and nitrogen, 250 atmospheres, and 1 kg. liquid for 1·34 litres capacity. For instance, a vessel of a capacity of 13·40 litres must not contain more than 10 kg. of nitrogen or liquid carbonic acid.

5. Great care must be taken not to drop the vessels full of liquid gases. They must be protected against the sun's rays and the heat of stoves.

6. They must be delivered in covered carts, or in specially-built carriages covered with wood.

Customs tariff

CUSTOMS TARIFF.

CALCIUM CARBIDE.

Germany	Import and export	free from duty.
Belgium	No. 53 of the Customs Regulations. "Chemical substance"	,, ,, ,,
Bulgaria		14 % of value.
Denmark	No. 53 of the Customs Regulations. Chemical products	10 ,, ,,
Finland	No. 115 of the Customs Regulations. Chemical materials and products. 100 kg.	18·80 Fin. mark.
France	No. 282 of the Customs Regulations. Chemical products are not mentioned	5 % of value.
Greece		duty free.
Great Britain		,, ,,
Italy	No. 59 of the Customs Regulations. Chemical substances not specially mentioned. 100 kg. (with packing, 12½ lire)	10 lire=8*s.* 4*d.*
Luxemburg	Belongs to the German Toll Union	
The Netherlands		duty free.
Norway		,, ,,
Austria-Hungary	No. 331 of the Toll Union Regulations. Chemical products not specially mentioned. 100 kg.	10 guilders.
Portugal	No. 148 of the Customs Regulations.	
Roumania	No. 148 of the Customs Regulations. Chemical products not specially mentioned	duty free.
Russia	No. 112 of the Customs Regulations. Chemical products which are not specially mentioned. Per pood, 16 kg.	2·25 paper rouble.
Sweden	No. 284. Chemical technical products not particularly specified	15 % of value.
Switzerland	No. 15 of the Customs Regulations. Chemical and other products not mentioned. 100 kg.	8 francs.
Servia	No. 241 of the Customs Regulations. Calcium carbide. 100 kg.	·10 peseta=¾*d.*
Turkey	All sorts of merchandise	8 % of value.
Japan	No. B a 4 of the Customs Regulations	4 ,, ,,
Dutch East Indies	All sorts of merchandise	6 ,, ,,
Persia	,, ,, ,,	5 ,, ,,
Argentine Republic		25 ,, ,,
Brazil	No. 328 of the Customs Regulations. Chemical products not specified	50 ,, ,,
Chili		5 ,, ,,

Customs tariff (cont.)

Canada	No. 147 of the Customs Regulations. Chemical products	25 % of value.
Mexico	No. 704 of the Customs Regulations. Calcium carbide	duty free.
Egypt	All sorts of merchandise	8 % of value.
The Cape		9 „ „
South African Republic		7½ „ „

ACETYLENE APPARATUS

Duty on Acetylene apparatus

made of steel and cast iron, painted and with fittings of other metals and alloys.

Germany	Export free. No. 6 e 3B of the Toll Tariff. Goods made of tin plate and cast iron. Per 100 kg.	24 marks.
Belgium	No. 33 of the Customs Regulations. Engines, mechanical apparatus, tools. 100 kg.	4 francs=3*s*. 2½*d*.
Bulgaria	Factory apparatus	8 % of value.
Denmark	No. 174 of the Customs Regulations. Per lb.	3*s*.
Finland	No. 231 b 1 of the Customs Regulations. 100 kg.	14·70 F. marks.
France	No. 525 of the Customs Regulations. Mechanical apparatus. 100 kg.	10 francs.
Greece	No. 252 of the Customs Regulations. Apparatus for industrial use.	duty free.
Great Britain		„ „
Italy	No. 240 of the Customs Regulations. Apparatus not specified. 100 kg.	10 lire=8*s*.
Luxemburg	Belongs to the Toll Union	duty free.
The Netherlands	Hardware	
Norway	No. 341 of the Customs Regulations. Apparatus for industrial use	10 % duty free.
Austria-Hungary	No. 286 of the Customs Regulations. Engines and apparatus of ordinary metals	12 guilders.
Portugal	No. 372 of the Customs Regulations. Apparatus of any kind up to 50 kg., 60 reis; 50 to 100 kg., 50 reis; 100 to 500 kg., 40 reis 500 to 1,000 kg., 30 reis; 1,000 kg. and more	20 reis.
Roumania	No. 503 of the Customs Regulations. Engines and apparatus of cast or hammered iron, with other metals for fittings. Per 100 kg.	12 lei.
Russia	No. 167 of the Customs Regulations. Engines and apparatus of cast or hammered iron, with fittings of other metals. Per pood, 16 kg.	1·40 gold rouble.
Sweden	No. 369 of the Customs Regulations. 100 kronen	10 kr.

Duty on Acetylene apparatus (cont.)

Switzerland . .	No. 250 of the Customs Regulations. 100 kg. apparatus for generating acetylene. 100 kg.	4 francs.
Servia . . .	No. 278 of the Customs Regulations. Engines for industrial purposes .	duty free.
Spain . . .	No. 268 of the Customs Regulations. Engines not specially mentioned. 100 kg.	20 pesetas.
Turkey . . .	All sorts of goods	8 % of value.
Japan . . .	No. 17 of the Regulations of the Union. Engines not specified .	10 ,, ,,
China . . .	Engines	5 ,, ,,
Siam . . .	All sorts of goods	3 ,, ,,
Persia . . .	,, ,, ...	5 ,, ,,
Egypt . . .	,, ,, ...	8 ,, ,,
The Cape . .	No. 95 of the Apparatus Regulations. Gas lighting apparatus . . .	duty free.
South African Republic—Transvaal	. . . .	$12\frac{1}{2}$ % of value.
Argentine Republic	Gas light apparatus	duty free.
Brazil . . .	No. 929 of the Customs Regulations. Engines and apparatus . . .	15 % of value.
Chili . . .	. . . .	duty free.
Mexico . . .	No. 802 of the Customs Regulations. Engines and apparatus for industrial purposes. Per kg. brutto . .	0·05 peseta.

ACETYLENE PATENTS.

I. PATENTS FOR ACETYLENE GENERATORS AND LAMPS.

Lamp for Burning Acetylene.

An iron or steel cylinder lamp in which cartridges of carbide coated with gelatine, glue, or soluble varnish are decomposed by dropping them into water. The gas is allowed to accumulate under pressure in the reservoir of the lamp.

Gearing, E. G. Harrogate 22183 Nov. 16, 1894

Producing Acetylene.

An automatic generator in which water is allowed to drop upon the carbide. When the pressure of gas within the generator reaches a certain point, a collapsible vessel attached to the top of the generator rises and cuts off the supply of water.

Gearing, E. Harrogate 25203 Dec. 28, 1894

Generating Acetylene Gas.

Within a vessel adapted to hold water there dips a second smaller vessel open at the bottom and closed at the top, the annular space between being open to the main vessel. Within the inner vessel there is suspended a carbide supporter or carrier, perforated and in the form of an inverted cone. The vessels are charged with water to a level above the bottom of the carbide carrier and acetylene is generated, but as the pressure of gas increases it depresses the water level within the inner vessel until it is out of contact with the carbide. Thus the generation of gas only proceeds when the pressure of gas within the generator is below a certain limit.

Morrison, D. B. Hartlepool 2437 Feb. 4, 1895

Apparatus for Producing and Liquefying Acetylene.

Liquefies the gas by its own pressure.

Dickerson and Suckert New York 5730 Mar. 19, 1895

Generating and Storing Acetylene.

An automatic generator in which water is sprayed over the carbide. The generator consists of an outer part resembling a gasholder, which is sealed by water contained within an annular receptacle. The surface of the water is preferably covered with oil to prevent evaporation. The carbide is placed within a perforated basket, and above it is fitted a sprayer.

Gearing, E. Harrogate 6777 Apr. 2, 1895

The gas is led into a gasholder, which, when nearly filled, automatically cuts off the supply of water to the generator.

Acetylene Gas Lamp.

Rossbach, Roussett Berlin
11783
Jun. 17, 1895

The supply of water to the carbide is regulated automatically by the pressure of the gas. The water for the decomposition of the carbide is partly distributed in fine particles over the carbide by the aid of wicks, which draw water from the lower part of the reservoir.

Producing Acetylene Gas.

Dickerson, E. N. New York
11848
Jun. 18, 1895

An automatic generator in which carbide falls upon a perforated plate below the level of the water. The waste lime is collected in a tray at the bottom of the generator, and is drawn out through the water by means of a chain and raising tackle.

Supplying Acetylene Gas.

Dickerson, E. N. New York
11848*b*
Jun. 18, 1895

It is claimed that by a certain arrangement of reducing valve, expansion coil, gasholder, and safety valve, practical combustion of liquefied acetylene is for the first time rendered possible.

Generating Acetylene Gas.

Exley, J. H. Huddersfield
12341
Jun. 26, 1895

Two vertical generators are fixed to the side of a receiver, which in turn is connected with a water cistern placed immediately above it. The cistern is connected to the receiver by a pipe extending below the minimum working level of the water in the receiver. The generators are connected to the receivers by a water passage and a gas passage, and are fitted at the bottom with discharge taps. Wire or perforated metal cages to hold the carbide are placed in each generator.

Gas-producing Lamps.

Thorp and Marsh Manchester
12355
Jun. 26, 1895

Three forms of acetylene lamp. No. 1 is charged by turning the lamp upside down, the carbide and water being placed in their respective receptacles. When the lamp is turned over to its normal condition the water runs out of its receptacle and comes in contact with the carbide. Nos. 2 and 3 are charged from the top. The carbide is placed on a perforated shelf, which is fitted over a false bottom provided with a central aperture in the generator. The water is added until it nearly reaches the perforated plate, and then a slight shake of the lamp starts the generation of gas.

Production of Heating and Illuminating Gas.

Thorp and Marsh Manchester
12356
Jun. 26, 1895

A floating bell rendered buoyant by air-tight chambers is suspended in a tank of water. In the bell is fitted a perforated shelf at some distance from the bottom, while the top is finished with a gas-tight hopper through which the carbide can be

inserted. The bottom of the chamber is preferably concave, and is provided with a small pipe or aperture to admit the water. In one form of apparatus without the floating bell the gas production is started by simply adding water to the containing tank, and in a second form by lowering the bell until the carbide comes in contact with the water.

An Automatic Apparatus.

Water falls upon the carbide, and the gas produced from it passes into a holder. The cocks leading to the holder and to the water supply are so arranged that they are automatically regulated by the pressure of gas within the generator.

Gabe, H.
Copenhagen
15991
Aug. 26, 1895

Production and Utilisation of Acetylene.

Generator No. 1 is for producing acetylene at all pressures, No. 2 is a low pressure apparatus, and No. 3 is a portable acetylene lamp. The carbide is placed in perforated cylinders, which have sufficient space left around them when placed in position to allow the water to act freely upon the carbide. The water is passed from an upper reservoir to the lower receptacle, in which the carbide cylinder is placed, and thus rises around the carbide. For the lamp, provision is made when desired for an accumulator for regulating the pressure of the gas and for a dessicating chamber.

Ducretet, E.
and
Lejeune, L.
Paris
16502
Sep. 3. 1895

Generator for Acetylene Lamps.

This invention is to secure a full pressure immediately the lamp is lighted, and to stop generation of acetylene as soon as the light is extinguished.

Campe, R.
Berlin
16691
Sep. 6. 1895

Decomposing Carbide of Calcium.

Two forms of generator. In one the holders containing the calcium carbide are lowered into the water, in the other the water rises around the carbide. The charge holders are perforated to admit the water to the carbide, which is packed in layers alternated with discs of waterproof material, so that only the immersed portions of the charge will be saturated. For the second form a condenser with a filter is employed between the holder and the generator.

Gabe, H.
Copenhagen
17746
Sep. 23, 1895

Acetylene Gas Generating Lamp.

Automatic acetylene lamp. An upper vessel containing water is attached to a lower one containing carbide. The water percolates through a felt filter before coming in contact with the carbide.

Kaestner, C.
Halle on
Saale
18821
Oct. 8 1895

Generating and Regulating the Consumption of Acetylene Gas.

Bayley, J. C.
Bournemouth
19771
Oct. 21, 1895

This apparatus in its most simple form consists of an inverted cylinder having its upper end either closed or made to open and its lower end open, the plates forming the bottom having their lower edges serrated or perforated. Near the top are placed one or more perforated trays to carry the carbide. The vessel is placed, open end downwards, in a tank of water. From the interior of the inner vessel a pipe communicates direct with the burners. When the gas in the generator accumulates under pressure the water is driven away from the carbide, and further generation should cease until the consumption of the gas allows the water to return to the carbide.

Generating Acetylene Gas.

Exley, J. H.
Huddersfield
20453
Oct. 30, 1895

A modification of the apparatus described in a former patent. An automatic valve is introduced in the gas passage between the generator and the holder, adapted to close when a certain quantity of gas is contained in the holder, and prevent further generation of gas by at once expelling the water from the generator.

Manufacture of Acetylene Gas.

Atkinson, J. E.
Liverpool
20468
Oct. 30, 1895

Two generators connected to an overhead cistern are each provided with a loose perforated carbide holder so arranged as to be easily placed within or withdrawn from the generator through a door in the side. The pipe from the cistern to the generator bifurcates, and is fitted with a two way cock, so that the supply can be turned into either of the two branches. Each branch is controlled by a regulating cock operated by the rising and falling of the gasholder-bell.

Generating Acetylene.

Exley, J. H.
Huddersfield
20727
Nov. 2, 1895

Another modification with the object of bringing automatically the second generator into operation as soon as the carbide in the first is exhausted.

Producing Acetylene.

Trouve, G.
Paris
23521
Dec. 7, 1895

A generator of acetylene gas comprising a stoppered vessel, apertured at the bottom, immersed in water, and enclosing a suspended wire cage containing carbide crystals arranged in superposed layers separated by glass discs, so as to cause the successive immersion of the layers and ensure a uniform production of gas. The apparatus may be combined with a gasholder for the storage of the gas from one or more generators. The inventor also proposes a combination in a portable lamp for

burning acetylene, of means of generating the acetylene, and of two concentric and connected tubes, one for conveying the gas to the burner, and the other being adapted to siphon off the water condensed in the gas tube.

A Prepayment System.

In order to effect distribution of the gas on prepayment of a certain coin, mechanism is arranged to deliver a measured quantity of water to the generator, only just sufficient to produce the required quantity of gas from the carbide. In this generator water from an overhead tank flows through a spraying rose on to the carbide. The gas generated passes through a condenser and finally enters a gasholder.

Synnock, W. and Gosling, G. Peckham, London
24088
Dec. 16, 1895

Acetylene Gas Generator.

This apparatus consists of a double tank so formed as to leave a space between the chambers designed to contain water under pressure, which is forced in by a suitable pump arranged upon the outside of the tank or chamber. Within the inner chamber is provided any suitable number of cells, each designed to contain carbide and calcium oxide or stone lime, the latter being inserted to prevent smoking. Around and over the cells is a pipe connected with the outer tank containing water under pressure, so that the water may be admitted to one, two, or all the cells as required. This is effected by opening a valve or cock corresponding with the cell required.

Warn, W.W.R. and King, L. F. Poole
75
Jan. 1, 1896

Generating, Storing, and Purifying Acetylene.

This apparatus in its simplest form consists of a vessel inside which a float is inserted through an opening in the top which can be closed air-tight. The float is composed of two concentric cylinders, the inner of which has an end which closes it. The outer cylinder extends some distance above the top of the inner float so as to form a receptacle for the carbide, and between the two cylinders a small annular space is left which is filled with a ring of some textile material. The whole of the float is free to rise and fall between vertical guides, and it is borne by the weight of the water. Upon one side of the top of the vessel is placed a water tank, so arranged with a ball cock and an overflow pipe that a uniform level is maintained. Upon the other side of the top of the vessel is arranged a container for lime or other purifying agent. A frame or grating is arranged inside the vessel underneath the float by which it can be lifted to the top of the vessel.

Bayley, J. C. Bournemouth
322
Jan. 6, 1896

Production of Acetylene Gas.

Rosbach
Rousset F.
Templehof
1116
Jan. 16, 1896

The carbide is contained in an open tray placed in a chamber through which passes the water supply pipe, the latter being so enlarged as to form a small condensing chamber along that portion directly above the carbide. The water is allowed to flow in unregulated quantity upon the carbide, and produces within the generator a pressure exceeding that normally required for the development of the gas flame. The excessive pressure forces the water back along the supply pipe and thus stops the further supply. The heat in the generator is now so great that part of the water is converted into steam, which, however, condenses in the enlarged water supply pipe and in a short time overflows from this pipe and falls upon the carbide.

Generating Acetylene.

Luis, C. G.
London
1332
Jan. 18, 1896

The generator is divided by a horizontal partition into two chambers, the upper containing water and the lower carbide. The lower chamber is provided with charging apertures and with an outlet for removing waste residues. A pipe leading from the carbide chamber to a point above the surface of the water in the upper chamber is provided for carrying off the gas generated. The automatic generation of gas is effected by a floating valve comprising a hollow metal ball with a conical projection. The ball is furnished with a small tube extending downwards, open at both ends, and so arranged that when the ball is in the lowest position the lower end of the tube is nearly in contact with the partition. Curved bands are fixed to the partition to prevent the ball from rising too high in the water. The accumulation of pressure in the apparatus automatically closes the valve, stops the supply of water to the lower chamber and thus prevents further generation of gas.

Acetylene Generator and Container.

Thorn, F. S.
and
Hoddle, C.
London
3142
Feb. 12, 1896

This generator consists of two cylinders suitable for holding water, with an inverted cylinder inside, each connected by a U shaped tube passing from the top of No. 1 cylinder, which acts as the generator, through the bottom of each to the top of No. 2 cylinder, which acts as the gas container. Carbide is placed in a perforated holder suspended from the top of the inverted cylinder in No. 1. Both outer cylinders being filled with water and the stopcocks turned on, the gas will be generated in No. 1 as soon as the inverted cylinder sinks sufficiently to allow the carbide to reach the water.

Manufacture of Acetylene.

Pym, E. P.
and Gore, J.

Two generators are provided but are used alternately, so that while one is working the other can be cleaned out and recharged.

The charge of carbide is placed in baskets and water is allowed to flow over them. The gas generated passes to a storage reservoir, whence it passes to a second chamber, the top of which is a flexible diaphragm having fixed to its centre a weight sliding upon a guide pin. This second chamber is so constructed that the gas issues from it at a uniform pressure.

Clerkenwell
3219
Feb. 12, 1896

Portable Lamps.

Claims "the employment of acetylene in liquid or vapour form, under pressure, for use as a lighting agent in lamps of velocipedes, cycles, and other like structures."

Tice, W.
Westminster.
4478
Feb. 28, 1896

Production and Use of Acetylene.

An automatic generator consisting of two cylindrical reservoirs connected at the top with one another but shut off from one another, when desired, by cocks. The carbide is placed in these reservoirs and water is admitted from an upper tank by a bifurcated tube. The upper part of this tube is funnel shaped with a bulb below the funnel and a bend in which a little mercury is placed in order to prevent contact between the carbide and water vapour after the supply of water has been automatically cut off.

A burner consisting of two nozzles converging towards each other at a suitable angle is also claimed. As the gas jets encounter each other they are splayed out producing a flat flame.

Ragot, G.
Belgium
5279
Mar. 6, 1896

Generating Acetylene.

Relates to the use of carbide in portable apparatus, such as bicycle lamps. Alcohol is mixed with the water employed to decompose the carbide in order to retard the process of decomposition. One part of methyl alcohol to nine parts of water is the mixture recommended.

Turney, E. T.
Chicago
5375
Mar. 10, 1896

Automatic Generator.

An acetylene generator in which the carbide is suspended in a cage attached to a piston and fitting into an annular tube which passes through the top of gasholder, a screw cap and stuffing box closes the top of annular tube, and the piston carrying the carbide cage passes through it. A charge of carbide is placed in the cage, lowered into the tube, the cap is screwed up, and on pushing down the piston the carbide comes in contact with the water, acetylene is generated and the holder rises, drawing the carbide out of the water. As the gas is used, the holder descends and the carbide again coming in contact with the water gives off more acetylene.

Farnsworth, E.
Minneapolis
5624
Mar. 12, 1896

Production of Acetylene.

Holliday, T. **Huddersfield** 5813 Mar. 16, 1896

This apparatus consists of one or more generators and a displacement holder, the generators being placed on a level with or below the holder. The vessel which contains the carbide permits water to enter at a lower, and the gas to be withdrawn at a higher, level than the level of the carbide therein. The gasholder is one in which the acetylene is allowed to displace the water, which is thereby forced to a higher level and can re-enter the holder as gas is withdrawn from it.

Generating and Storing Acetylene.

Appleby, E. and Harris, H. F. **London** 5976 Mar. 17, 1896

This generator consists of a steel or iron cylinder in which the carbide is placed, and is fitted at the bottom with a cock for withdrawing the waste lime and water. The generator is connected to a gasholder, the bell of which is bolted down so that it cannot be lifted by the buoyancy of the gas. The tank of the gasholder is of sufficient depth to contain above the submerged bell all the water displaced from the bell when filled with acetylene. For the purpose of regulating the water supply to the carbide in the generator a ball float is placed in the holder tank above the bell. As the water in the bell is displaced by acetylene it rises in the tank and by means of the ball float cuts off the supply of water to the carbide. The gas is drawn off by a pipe from the dome of the bell passing through and above the water in the tank.

Generating Acetylene.

Webb, G. and Kelly, J. **London** 5905 Mar. 17, 1896

This invention relates to the automatic generation of acetylene by means of a head of water contained in a central partition gasholder acting upon carbide when the gas in the holder falls below a certain pressure.

Generating, Storing, and Purifying Acetylene.

Bayley, J. C. **Bournemouth** 6739 Mar. 27, 1896

Storage of the gas in contact with water is avoided. The gas as produced passes into a closed expansible and collapsible chamber contained in the storage cylinder or vessel, and the cistern into which the water is forced is mounted so that it can be raised or lowered as the water in it increases or decreases, and thus the head of water is kept constant. In some cases the storage cylinder is provided with a plain slab which floats on the top of the water, and, extending practically over the whole surface of the water, largely prevents the gas coming in contact with it. The generator is provided with a double valve operated by a single handle so as to admit and shut off water to and from and empty the generator and provide for the passage of the gas produced as and when required.

Generating Acetylene.

This apparatus consists in a combination of two vessels, one containing carbide, the other water. The vessels communicate with each other at their lower portion by means of a pipe provided with cocks for allowing liquid, etc., to pass from one vessel to the other and to be forced back. The first vessel is provided at its lower portion with a floating valve opening on the passage of the liquid and again closing when the liquid is forced back, thus preventing the escape of gas to the second reservoir. Communicating with the first vessel is a gas holder or pressure regulating reservoir provided with a gas outlet tube, the generator being furnished with a regulating arrangement automatically working a valve or cock on the pipe between the first generator and the gasholder for the purpose of governing the admission of gas into the holder, and to thus obtain a perfectly even flame at the burner.

Cerckel, A.
Paris
6719
Mar. 27, 1896

Generating Acetylene.

An automatic generator in which water from an upper reservoir falls upon the carbide. Two cylindrical generators are connected by pipes to two water tanks placed some distance above them. Between the tanks and the generators are placed valves, and the generators are connected at the side with a gasholder. The rising and falling of the holder automatically works the valves through which the water from the tanks falls upon the carbide, and thus the make of gas is automatically regulated by the rate at which the gas is withdrawn from the holder.

Clarke, W. C.
New York
7243
Apr. 2, 1896

Generating Acetylene.

A slight modification of the foregoing. The generators are placed one on each side of the holder instead of both on one side.

Clarke, W. C.
New York
7242
Apr. 2, 1896

Generating Acetylene.

This generator contains a series of superimposed trays in which the carbide is placed. Water is admitted at the bottom of the generator, and as it rises comes in contact with the carbide in the trays by suitable pipe connections attached to each tier of trays. The gas passes to a storage holder, and when this is full the pressure in the governor fixed to the top of the generator increases and, raising the bell of the governor, gradually cuts off the water supply.

Blakeley, J. F.
Ravensthorpe
5150
May 7, 1896

Acetylene Generator.

This apparatus embodies a generating chamber in which the carbide is placed, a water supply having its head above the level of the carbide, and a pipe leading from the water supply to the

Morley Acetylene Gas Co.

Wheeling, U.S.A.
10126
May 12, 1896

chamber having outlets above the carbide in the chamber. Water is allowed to issue from these outlets, and as the pressure of gas in the generator increases the water is gradually forced back, diminishing the supply of water to the carbide and finally stopping it altogether when the pressure becomes sufficiently great.

Portable Lamp.

Goodwin, R.
Dublin
10407
May 15, 1896.

On two sides of a lamp standard are fitted vertical cylinders with suitable caps and connections for the admission and control of fluids and gases. One cylinder, constructed of metal, contains water, and is fitted with a rack and pinion movement, intended to be wound up by a key. The water is forced by the pressure of a spring from this vessel into the other cylinder, which contains a carbide cartridge, and which is of glass with metal caps, and is provided with an internal wire gauze envelope for the carbide. The acetylene generated passes to a gas reservoir at the base of the standard, and from thence passes upward to the burner. By using a cartridge of mixed carbide and suitable carbonate, and using water acidulated with sulphuric acid, a mixture of acetylene with carbonic acid may be employed.

Generating Acetylene.

Webb, G. and Kelly, J.
London
10725
May 18, 1896

The patentees claim the use of a chamber or gasholder carrying a vessel containing carbide fitted with a central tube, the chamber or holder being in connection by a valve operated by a weighted lever with a collapsible bag containing water and provided with a weight for the purpose of forcing some of the water into contact with the carbide, so as to generate gas when the pressure of the latter has been reduced.

Acetylene Gas Lighting.

Moreau, G. and Poulties, A.
Paris
11581
May 27, 1896

This claims the use of mixtures of gas rich in carbon with combustible gases or gaseous mixtures, and more particularly the mixture of acetylene with hydrogen giving a nonfuliginous flame which produces great light. The installation comprises two distinct gasholders, one to contain hydrogen produced "by the customary process," and the other acetylene. The gases reach the burners simultaneously through branch pipes, where they form two converging jets producing a butterfly flame. Two meters may be used for preparing a mixture of acetylene and hydrogen, which may be stored in a single holder. There is also claimed an expanding burner with two convergent pipes through one of which acetylene is delivered and through the other a gas such as hydrogen is blown into the acetylene flame,

and thereby corrects and regulates it, the mixing not being able to take place before combustion.

Production and Storage of Acetylene.

This apparatus consists of two receivers one above the other, the upper containing water, the lower carbide. They communicate with each other by a tube fitted with a cock or valve, which may be opened or closed according to the rise or fall of the bell of a gasholder.

Clausolles, E.
Barcelona
11737
May 29, 1896

Generating Acetylene.

Two vertical cylindrical reservoirs enamelled internally communicate with each other at the top and bottom. In one is placed a pail or bucket with longitudinal grooves along its external surface to allow the water to pass into the bucket and come in contact with the carbide it contains. The second reservoir contains the water for the decomposition of the carbide. On opening the cock on the lower connection between the reservoirs the water runs into the carbide vessel and the gas escapes through the water reservoir.

Bauwer-aerts, E.F.J.C.
Brussels
11708
May 29, 1896

Generating Acetylene.

A generator and holder placed side by side. The generator is a receiver open at the top and containing water. Above the water level is placed a perforated basket containing the carbide. A bell-shaped cover descending to the bottom of the generator is loaded to form with the water a hydraulic seal. From the upper part of the carbide vessel a pipe communicates with a tube rising in the holder to nearly the level of the water, and around this latter tube another tube fixed to the bell of the holder slides.

Fourchotte, M. C. A.
Paris
12047
Jun. 2, 1896

Two generating chambers are employed alternately. The carbide is placed in perforated baskets in layers separated by layers of an inert substance such as gravel, slag, etc. A partition divides the basket vertically, so that the separated layers are acted upon in immediate succession. A purifier filled with wood fibre coke or other material is used to dry the gas.

Deroy, H. A.
Paris
12683
Jun. 9, 1896

Automatically Generating and Distributing Acetylene.

Water is caused to pass under constant pressure through a series of generators containing carbide in such a manner as to bring the generators successively into action, and arrangement is made to regulate the pressure of gas and to effect its distribution to the burners. An excess of water is provided which " by absorbing the caloric developed in the generators prevents the temperature rising therein."

Tobler, A.
Garenne
12662
Jun. 9, 1896

Generating and Storing Acetylene.

Gibbs, R. R.
Egremont
12788
Jun. 10, 1896

A tank with counterbalanced gasholder has a central pipe rising from the bottom of the tank, another pipe surrounding it and acting as a guide. The tank is filled with water to a convenient height and a thick layer of oil is poured on it. The carbide is fed into the holder by a device on the top.

Manufacture of Acetylene.

Atkinson, J.E., Labourchere, J. M.
Liverpool
13147
Jun. 15, 1896

A gasholder and water tank with generators for the carbide separately connected to the water tank by an air vessel and non-return valve. The generator has a perforated conical top through which the water passes, the quantity being regulated by the rise and fall of the water in the bell. A seal is attached to act as the holder descends to permit of the removal of the waste material.

Generation and Storage of Acetylene.

Bowers, A. F.
Paris
13511
Jun. 18, 1896

The essential features are—a regulating chamber into which the extremities of the water supply pipes of each of the generators project to varying depths, so that as the water level rises owing to pressure of gas the next generator can be set in action. A return by-pass pipe from the carbide holder to the water reservoir so that on excessive pressure being attained even after the water supply is cut off the remaining water is returned to the top of the water reservoir.

Producing Acetylene Gas.

Ackermann, F. P. J.
Marseilles
14278
Jun. 27, 1896

A fixed gasholder has a generator on either side, the supply of water being taken from the gasholder. The connecting tube of one generator is fixed at a lower level than that of the other, so that the carbide in one is exhausted before the other is attacked. The production of gas is continuous, as the waste carbide can be removed from the one holder whilst the other is working.

Production and Combustion of Acetylene.

Schulke, A. H. J.
Berlin
14929
July 6, 1896

This apparatus is composed of a generator consisting of a water vessel in which is a bell closed at the top and provided with a tap through which the gas is withdrawn for consumption. The upward movement of the bell is limited by stops. Inside the bell are claws forming supports for the removable basket containing the carbide. The bell is lowered till the carbide reaches the water, when the generation of gas raises the bell and removes the carbide from the water, the operation being repeated as the gas is consumed. A weighted receiver is used to obtain a more uniform pressure. The burner consists

of a number of small tubes issuing from a chamber placed at such a distance apart as to admit of free access of air between them. A chimney may be used to increase the supply of air.

Production of Acetylene.

The generator is provided with a cover having a hydraulic joint, and formed by a bell held in position by a pivoted bar. The carbide receiver is divided into a number of compartments communicating with each other in such a manner that the water overflows from one to the next. The gas is washed by passing it through the water in the holder, whence it passes through a purifier divided into two compartments, the lower containing pieces of pumice stone, or similar material, soaked in a saturated solution of copper sulphate or other suitable salt for the removal of phosphuretted hydrogen.

La Companie Continentale d'eclairage par le gaz acetylene, Paris
15064
July 7, 1896

Generating Acetylene.

A water tank is divided into three compartments by two horizontal partitions, the upper being filled with water and the lower forming the gasholder. Between the two, or at the same level outside the tank, is a small tank enclosed at top and bottom. Water is allowed to drop on to the carbide through a wick and perforated cylinder, the surplus gas enters the gas and water tank, and forcing back the water from the pipe supplying water to the generator prevents further generation of gas.

Haviland, F. H. Holloway, A. Collier, J. B. Burch, W. H. Bournemouth
15122
July 8, 1896

Acetylene Generator.

Inside the generator is a perforated metal holder resting on brackets some distance from the bottom and containing the carbide. The cover of the generator being placed in position the water supply tap is opened, and as the gas is generated it passes into a holder.

Whalley, D. Hacking, J. Blackburn
15654
July 15, 1896

Generating, Storing, and Cooling Acetylene.

The carbide holders are in the form of trays which can be hermetically closed in a cylindrical or other holder in connection with a gasholder. The trays are divided in such a manner that the water overflows from one to the next. The gas pipe acts as a condenser by passing through the water supply pipe to a cooling chamber provided with an outlet for the gas and a drain cock.

Thorn, F. S. Hoddle C. Camberwell
15962
July 18, 1896

Production of Acetylene.

A generator attached to a gasholder so arranged that as the bell of the gasholder sinks it operates certain mechanical devices and causes parcels of carbide to be pushed upon an inclined board and fall into water.

Boter, A. Barcelona
16345
July 23, 1896

Production and Purification of Acetylene.

Schemidt, A. Kauffman, O. Paris 16432 July 24, 1896

Carbide is added in small quantities to a large quantity of water. The generator is a flanged cylinder, the cover of which is secured by bolts, and attached to it is a slide and hopper into which the carbide is fed. The carbide falls upon a grid immediately below, which is fixed just below the level of the water in the generator. The carbide is kept agitated by a metal brush, so as to cause the lime to fall through the grid. A stirrer is arranged in the generator to agitate the water and prevent deposition of waste material. The gas is passed through a suitable acid solution to remove ammonia, a neutral solution of lead acetate to remove sulphuretted hydrogen, and an acid solution of copper sulphate to remove phosphuretted hydrogen, and, lastly, through a solution of caustic soda to remove any acid vapours. The gas then passes into a holder, and after being dried by passing over calcium chloride is pumped and liquefied.

Producing Acetylene.

Alexandre, F., Paris 16728 July 28, 1896

The carbide is placed in a porous vessel surrounded by absorbent material saturated with water.

Production of Acetylene.

FitzGibbon, L. T. London 17038 July 31, 1896

Carbide is made into balls or tablets by admixture with stearic acid, paraffin, and the like, and then coated with a substance such as a silicate. A gasholder is used with a device for intermittently distributing water to the carbide. The carbide holder immersed in water is divided into two compartments, the lower being perforated and the upper containing the carbide holder. The pressure of gas regulates the water supply.

Generating Acetylene.

Clarke, W. C. New York 17450 Aug. 7, 1896

Water falls on carbide from an upper vessel, the bottom of which is fitted with a valve normally closed and watertight, but opened by a rod projecting through the cover of the generator, thus allowing the water to attack the carbide.

Acetylene-supplied Street Lamp.

Clarke, W. C. New York 17451 Aug. 7, 1896

A generator is attached to a street lamp. The generator is provided at each end with a movable cover, the upper being fitted with a device for piercing the waterproof carbide cartridges used.

Acetylene Generator.

Duffield, M. Slough 17646 Aug. 10, 1896

A divided generator without valves is employed. The water supply is governed by the rise and fall of a gasholder. The water supply is connected with the generator with a syphon

pipe fitted with a tap. Each generating chamber is fitted with a number of perforated vessels for holding the carbide. An escape pipe is provided for any excess of gas.

Production of Acetylene and Carbonic Acid Gas.

A combination of a vessel for containing the carbide mixed with lime, chalk, or marble, a vessel from which acidulated water is supplied in regulated quantities, and a vessel divided into three compartments by perforated partitions, the upper containing sulphate of copper, the centre wire filling for mixing the gases, the lowest serving to collect separated impurities.

Goodwin, R. **Dublin** 17644 Aug. 10, 1896

Generating and Liquefying Acetylene.

A process for liquefying acetylene without the use of great pressure and high temperature. Means are provided for preventing the accumulation of excessive pressure by the generated gas, for preventing the generation of gas at a high temperature, and for mechanically increasing the pressure to liquefaction.

Fraser, A. C. **New York** 17678 Aug. 10, 1896 Cl. Feb. 21, 1896

Generating Acetylene.

Granulated carbide is automatically distributed in the generator. Glass windows are fitted in the bell of the holder to enable inspection of the carbide and the level of the water to be made.

Grenier, O. and Grand, J. **Lyons** 17904 Aug. 12, 1896

Purification of Acetylene.

The generator is provided with a jacket, through which flows a current of water, and within the generator is a refrigerating worm.

Pictet, R. P. **Geneva** 18208 Aug. 17, 1896

Producing Acetylene.

The apparatus consists of a water reservoir surmounted by a bell, and of a vessel containing granulated carbide, the fall of which into the water is regulated by the bell, which operates a feed valve in the carbide container.

Chivert, D. H. **Neuilly** 19059 Aug. 28, 1896

Producing Acetylene.

When the bell of the holder is in its lowest position, water from a reservoir trickles on to the carbide. The gas is cooled by passage through a worm, and flows into the holder, which rises and cuts off the water.

Voigt, G. **Berlin** 19126 Aug. 29, 1896

Generating Acetylene.

This apparatus is designed for subjecting the carbide progressively to the action of the liquid, a reserve of carbide being used to dry the gas. The carbide is supplied in small quantities to avoid compacting the mass and causing it to swell, thus preventing the free passage of the generated acetylene through it.

Fuller, H. F. **Chicago** 19288 Sep. 1, 1896

Generating and Storing Acetylene.

Gaskell, G. W. and Gibbs, R. R. Liverpool 20074 Sep. 10, 1896

The generator is separated from the gas chamber by a water seal, and is so designed as to admit of re-charging without escape of acetylene while the holder is in use. The carbide is withdrawn from the water by the ascent of the bell and immersed again on its descent.

Generating and Storing Acetylene.

Chesnay, E. and Pillion, L. Dijon 20090 Sep. 10, 1896 Cl. Feb. 13, 1896

Modification of a previous patent. The generator is a cylindrical vessel, in the top of which the carbide holder is supported, water being in the lower portion. To the lower part of the generator is attached by a flexible tube a vessel of water which is raised or lowered by the rise or fall of the holder. When the vessel is raised water rises to the carbide. On the surface of the water in the generator is a layer of oil, forming a hermetic seal when the apparatus is at rest.

Generating and Storing Acetylene.

Chesnay, E. and Pillion, L. Dijon 20254 Sep. 12, 1896 Cl. Feb. 25, 1896

A modification of the foregoing. Instead of the movable water vessel, a fixed vessel containing water is provided, which is connected to the generator by a pipe at its lower end. Inside this vessel is a displacement cylinder, which may be either solid or hollow. The movement of the bell causes this cylinder to rise or fall, thus causing the water to attack or leave the carbide.

Acetylene Lamps.

Trost, R. Switzerland 20406 Sep. 15, 1896

Two forms of table lamp generator, in which water drips upon carbide. In one form the water flows from an upper reservoir into a syphon pipe, composed in its upper portion of metal, and its lower V-shaped portion of india-rubber. In the water reservoir is a float, which by means of a bent wire is connected with the plug which regulates the water discharge from the syphon tube. The supply of water to the carbide is automatically regulated by the pressure within the gas reservoir. In another form an inflexible syphon pipe is employed, and this pipe opens into a water reservoir, which is connected with the outside air, and also with an hermetically closed water reservoir. No float is employed, but as in the first form the accumulation of pressure to a certain point prevents the further discharge of water over the carbide.

Production of Acetylene.

Gastine G. S. J. Marseilles 20529 Sep. 16, 1896

This apparatus consists of two parts: one, the generators to the number of two or more, used alternately; the other a regulator, which acts automatically on the generator controlling the evolution of gas.

Acetylene Gas.

Tablets of carbide are automatically dropped into water by means of a mechanical arrangement actuated by the rise and fall of a holder to which the generator is connected.

Deuther, J.A. Boston, U.S.A. 20599 Sep. 17, 1896

Production of Acetylene.

Lumps of carbide are fed on to a grating immersed in water and placed in the lower part of a cylindrical generator. The carbide is fed through a shoot. The level of the water in the generator is controlled by a hydraulic sealed overflow.

Pintsch, J. Berlin 20602 Sep. 17, 1896

Generating and Storing Acetylene.

The generator containing a perforated carbide basket is attached to the side of a fixed holder containing two worms. Two tubes controlled by a single tap place the upper and lower parts of the holder in communication. Water from the tubes flows on to the carbide, when the gas drives the water from one coil and enters the upper part of the holder, whilst it prevents the further contact of water to the carbide. A float in the upper part of the holder, connected to an electric alarm, indicates when the water is at the lowest point.

Commuci, V. T., San Giovanni, Italy 20694 Sep. 18, 1896

Acetylene Manufacture.

Carbide is placed in a tube holder attached to the top of a gasholder bell, and the gas is generated by the fall of the bell. A blow-off is provided for excess of gas, and an exit tube for removal of waste lime.

Sardi, V. Turin 20903 Sep. 21, 1896

Generating and Storing Acetylene.

The generating vessels are supported in an inclined position by means of standards, and connected to condensing vessels fitted above them at a similar angle. From the condensers the gas passes to the holder.

Water is admitted very gradually to the carbide, and when one generator is exhausted, water is admitted to the second. When the holder rises to a certain height, the water supply is automatically cut off.

Kay, A. Doune, N. C. 21351 Sep. 26, 1896

Acetylene Generators.

The carbide is placed in a perforated basket in a generator fixed at the side of the holder. The water is supplied from the holder tank, and the rise and fall of the bell alternately dips and withdraws the carbide from the water. An air cylinder is fitted in the bell for the purpose of mixing air with the acetylene.

Kon, S. Warsaw 21468 Sep. 28, 1896

Generator for Acetylene.

Barker, A. H.
London
21698
Sep. 30, 1896

The generator is provided in the upper part with a carbide holder, to which water is supplied from a cistern at a higher level. The generation of gas is controlled by the movement of a gasholder placed above. To prevent admixture with air on charging, a device is used by which a small quantity of acetylene is generated in the carbide holder before it is connected with the holder.

Generating and Storing Acetylene.

Chesnay, E. and Pillion, L.
Dijon
21758
Oct. 1, 1896
Cl. Apr. 1, 1896

Round the upper part of the holder tank is an annular receptacle, so arranged as to balance the weight of the holder, to which it is connected by chains passing over pulleys. This receptacle communicates with a vertical cylindrical generator by means of a rubber pipe at the lower end, and another rubber pipe leads from the top to the top of the holder. Another pipe leads from the top of generator to top of holder for the passage of the gas. The movement of the bell regulates the supply of water to the carbide.

Acetylene Generators and Holders.

Maddock, E. H. and Jones, W.
Liverpool
22359
Oct. 8, 1896

An annular exterior chamber is fitted round the gasholder tank, and is divided by partitions into several compartments, in each of which is a carbide holder. The external chamber is filled with water till the lower part of the holders is just covered. From each compartment a pipe fitted with a valve to prevent back rush of gas is led to the gasholder.

Production of Acetylene.

FitzGibbon, L. J.
London
22526
Oct. 10, 1896

Blocks of carbide are formed by mixing granulated carbide with paraffin. The generator is a cylindrical vessel fitted at the top with an outlet tap, and at the side with a feed tube, which rises above the top of the generator. Water is poured in up to three-fourths of the height of the generator, well above the inlet of the feed tube, and carbide is dropped in through this tube. The gas escapes into a holder.

Producing and Storing Acetylene.

Morton Brown, E. A. and Maundrell, F.
Woodstock
22628
Oct. 12, 1896

Thirty-one claims. A generator which can be shaken to free the carbide from lime, a condenser located in the water tank of gasholder, and an automatic arrangement for regulating the water supply.

Generator, Purifier, and Holder.

Smith, A. G.
Aberdeen
22646
Oct. 13, 1896

The generator consists of an outer vessel to contain water, in which a movable bell is immersed. The carbide holder is a perforated tube having two projecting arms, and is suspended

within the gas bell. Inside the bell is an arrangement of wire which furnishes guides for the arms on the carbide holder, which is slipped between the guides, then given a quarter turn, and allowed to rest on ledges provided by the wire arrangement. A condensing pipe passes from the bell through the water tank to a chamber at the bottom of the generator. After leaving the condensing chamber the gas passes through a vertical tubular purifier, filled with broken pumice, which is situated at the side of the water tank. The rise of the gas bell draws the carbide from contact with the water, and its descent through withdrawal of gas renews the contact.

Generator for Cycle Lamps, etc.

Smith, J. S. and Smith, A. G. 22647 Oct. 13, 1896

Generator consists of an outer cylinder with a slip-on lid (pierced with a minute hole), to which is attached an inner bottomless cylinder of less diameter. In the inner tube is fixed a carbide container. The container consists of discs fixed on wires of suitable thickness, or it may be a perforated tube held in position by a wire. The container is held up in the cylinder by a bayonet-fixing at the bottom, or by other means. Communication between the inner and outer cylinders is effected by means of a pipe terminating in a stop-cock upon the cover of the outer cylinder. When generation of acetylene proceeds more rapidly than is required, the gas pressure accumulates within the generator, and forces back the water from contact with the carbide.

Manufacture of Acetylene.

Becherel, C. F. J. B. Paris 23289 Oct. 20, 1896

The water supply to the carbide is regulated by a float in a water reservoir above the gasholder. The float is connected to the holder by a rod, and is so arranged that the water flows on to the carbide when the holder sinks, but is cut off again when it rises.

Manufacture of Acetylene.

Becherel, C. F. J. B. Paris 23290 Oct. 20, 1896

An improvement on the foregoing. A generator or number of generators for containing calcium carbide, and which can be brought into operation successively. A vessel for containing the water supply, regulated by a float or floats. An extensible gasholder either of the ordinary form or in the form of bellows.

Producing and Storing Acetylene.

Trouvé, G. Paris 23591 Oct. 23, 1896 Cl. Apr. 14, 1896

Improvements on a previous patent. The generator is constructed entirely of metal, the stopper for closing the mouth of the bell being dispensed with, whilst the carbide cage is supported by a stand instead of being suspended.

Producing and Storing Acetylene.

Trouvé, G.
Paris
23592
Oct. 23, 1896

Further improvements. A novel condensing arrangement. The addition of a syphon to the generator, to prevent loss of gas generated in excess.

Production and Treatment of Acetylene.

Oving, H. E.
Rotterdam
23669
Oct. 24, 1896

Acetylene is generated by dropping water on carbide from an overhead funnel. The gas passes through a condensing coil in the holder tank to the bell, from which it passes to an apparatus for admixing air with it. This consists of a shaft carrying two or more drums of sheet zinc, partly dipping into water and provided with helical blades. A nozzle enters each drum in front of the first blade, one serving to admit acetylene and the other air, the whole being covered with a metal drum. The mixed gases pass to a tank after traversing a purifier and drying chamber.

Producing Acetylene.

Colberg, H.
Barcelona
23812
Oct. 26, 1896

Granulated carbide is placed in a receiver with a conical base, which is provided with a valve, and which is connected with the bell of the holder. The movement of this bell opens and closes the valve, causing carbide to drop into water or causing the supply to stop.

Generating Acetylene.

Mackenzie, W. J.
Glasgow
23752
Oct. 26, 1896

Two generators placed beneath a gasholder. Each generator consists of a water tank, in the centre of which is the carbide holder, over which is fitted a double cased vessel, the lower end of which dips into water tank, forming a water seal between it and the carbide cage. From this tank a pipe leads to the carbide cage. The movement of the gasholder regulates the water supply.

Production and Combustion of Acetylene.

Turr, R.
Paris
24274
Oct. 30, 1896.

Two concentric vessels (the inner closed, the exterior open), filled with water, and a carbide cage. The water is covered with a layer of toluol or petroleum. The supply of water is controlled by the pressure in the apparatus.

Acetylene Generator.

Smith, A. J.
Smith, A. G.
Aberdeen
24414
Nov. 2, 1896

The generator is fitted to the side of a displacement gasholder, the upper part of which is filled with water; the lower contains gas. Water is brought to the carbide by a U tube. The gas passes through a purifier to the holder forcing the water back from the carbide till the pressure is removed.

PATENTS FOR ACETYLENE GENERATORS

Manufacture of Acetylene.

Resener, P. and Luchaire, H. Paris 24440 Nov. 2, 1896 Cl. June 8, 1896

The essential parts are a vessel filled with water, a gasholder or bell immersed in the water vessel, and two carbide holders. The water supply for the carbide is taken from the water in the tank and is automatically regulated.

Acetylene-producing Lamps.

Hanotier, V. and Hostelet, G. Belgium 24558 Nov. 3, 1896

A lamp consisting of a water receptacle communicating with the carbide holder by a syphon tube. The longer arm of the syphon is much wider than the shorter and is curved inwards. At a certain distance above the bottom of the syphon is a small hole, whilst the longer arm is carried through the gas way in the centre of the water vessel. At the top of the gas way there is a recess into which the burner is screwed.

Generating and Storing Acetylene.

Kay, A. Doune, N. B. 24611 Nov. 4, 1896

Water is admitted from the gasholder tank on to carbide contained in inclined holder in a fine stream or spray. The gas passes through condensers through a back pressure valve into the gasholder. The water supply is controlled by the movements of the gasholder by means of a floating ball or disc connected with a weighted valve lever, which is actuated by a rod fixed in the bell.

Production of Acetylene.

Bablon, J. Paris 25224 Nov. 10, 1896

Five different forms of apparatus. Powdered carbide is fed into water, the supply being governed by a gas meter fitted to the delivery pipe of the gasholder.

Acetylene-producing and Storing Apparatus.

Chesnay, E. and Pillion, L. Dijon 25236 Nov. 10, 1896 Cl. May 9, 1896

A carbide hopper communicates with a water vessel by means of an inclined tube. The water vessel is connected to a gasholder by a flexible pipe. An archimedean screw operated by a small motor is fixed in the tube connected in the carbide hopper and water vessel, the motor being controlled by the movements of the gas bell.

Producing Acetylene Gas.

Fournier, A. Paris 25488 Nov. 12, 1896.

In the centre of the dome of a gasholder bell is a cylindrical box of conical shape closed at the top and having a conical opening closed by a valve at the bottom. The valve is fixed to a rod with a weighted base. As the bell descends the rod strikes the bottom of the holder tank, thus admitting some carbide, the valve being closed as the bell rises.

Producing Acetylene.

Vaughan-Sherrin, J. **London** 26897 Nov. 26, 1896

Several generators connected with a gasholder. As the bell sinks a signal is made and another carbide vessel put in action by opening its tap to the water vessel.

Acetylene Gas-lighting Apparatus.

Gillett, S. **Forest, G.** **Bocande, J.** **Paris** 27085 Nov. 28, 1896

A generator containing a carbide holder on to which the water is allowed to fall drop by drop. The gas is led into a water-filled reservoir, whence it drives the water into a higher reservoir through a plunger tube, so that the height of the water above the outlet is caused to decrease, thus diminishing the rate of flow of the water.

Manufacture of Acetylene.

Hargreaves, A. **Paris** 27194 Nov. 30, 1896

A regulated quantity of water is fed through a sieve hopper arranged in a body of water in a closed vessel to a revolving tray a short distance below the water. The bottom of the generator is conical, and the waste lime is removed, a similar quantity of fresh water taking its place. The carbide is mechanically fed into the apparatus. The gas is led through purifiers containing respectively sawdust or fibre soaked in dilute sulphuric acid, trays of finely divided oxide of iron, layers of crushed copper sulphate and moist sawdust, and finally dried over carbide.

Generating Acetylene.

Meyer, G. **Zurich** 27212 Nov. 30, 1896

A gasholder with an automatic water feed to supply to the generator a measured quantity of water when the volume of gas in the holder sinks below a certain limit.

Producing Acetylene.

Gossart, E. **Chevallier, H.** **Bordeaux** 27574 Dec. 3, 1896 Cl. May 5, 1896

Three forms of lamp. Water falls drop by drop from the upper part of the lamp on to carbide stored in the lower portion, passing through several bent capillary tubes which serve as safety valves.

Acetylene Generator.

Hanotier, V. **Hostelet, G.** **Belgium** 27697 Dec. 4, 1896

Water from an overhead supply falls through holes in a bulb on to a conical screen, whence it is uniformly distributed over the carbide. In case of excessive generation of gas the supply of water is stopped. The gas is passed over brown hæmatite, and cooled by traversing the tube passing through the water reservoir; then it is bubbled through more water and passed over quicklime.

PATENTS FOR ACETYLENE GENERATORS

Acetylene Generator, Purifier, and Container.

A screwed rod carrying at its base carbide holders passes through the top of a gasholder. The rod is screwed down till the carbide touches the water. The purifier is placed below the gasholder and contains mixtures such as lime and charcoal.

Fowler, T. R.
Liverpool
28206
Dec. 10, 1896

Producing Acetylene.

A water reservoir is provided with an overflow, a discharging pipe and an outlet for the gas, and a safety tube. The carbide container is inserted in the top of the reservoir, and contains a lateral orifice for inserting the carbide, and a regulator in the form of flexible bellows actuating a distributing valve, which is kept closed by the pressure of the gas and drops slightly when the pressure falls, allowing more carbide to fall into the water.

Gerard, L.
Paris
29188
Dec. 19, 1896

Producing Acetylene.

The carbide cage is placed in the bell of the gasholder, coming in contact with the water as the holder descends. A purifier of iron sulphate is used.

Richard-Lagerie, E.
Roubaix
29168
Dec. 19, 1896

Generating Acetylene.

Improvements on a previous patent. A small movable bell of rectangular shape is placed between the large bell and its containing tank, and connected to the large bell by a chain passing over pulleys, so that it rises when the bell descends and *vice versâ*. It acts as a regulator. The water runs on to the carbide at a rate regulated by the consumption of gas and controlled by the rectangular vessel.

Resener, P.
Luchaire, H.
Paris
29320
Dec. 21, 1896

Generating Acetylene.

Two gasholders are used, the first receiving the gas from the generator, whilst the second is used for service distribution. The carbide holder is attached to the first gasholder tank. An electric alarm is used to call attention for recharging.

Reynolds, D.
Winnebago, U. S. A.
29342
Dec. 21, 1896

Generating Acetylene.

This invention is to shorten the time of contact between the water and carbide, to prevent back rush of air into the apparatus, to maintain free communication between the holder and the generator, and to divide the carbide up so as to prevent too violent action.

Quelle, E.
Paris
29500
Dec. 22, 1896

Producing Acetylene.

A reservoir provided with the means of maintaining a constant water level is used, the lower part of it communicating with another reservoir, the upper part of which is open to the

Macé, P.
29596
Dec. 23, 1896

air. Above the first reservoir, is placed the carbide holder, the conical lower part of which is fitted with a valve mounted on a rod, at the bottom of which is a float. With diminution of pressure the water in the reservoir rises, carrying with it the float and opening the valve, thus admitting more carbide to the water.

Generators.

Spence, H. K.
Beveridge, A.
Kirkaldy
29554
Dec. 23, 1896

A casing to contain two carbide holders is fitted below a gas-holder, a space for water being left between, around, and below them. On the top of the casing are valves for admitting water, which are actuated by the movements of the bell. When one generator is exhausted the second is automatically brought into action.

Producing and Purifying Acetylene.

Dargue, W. H.
Newcastle
29768
Dec. 28, 1896

A generator containing a number of shelves to hold the carbide is fixed in a water jacket at the side of the gasholder, the water supply being taken from the tank. The movement of the bell regulates the water supply.

Producing Acetylene.

Resener, P.
Paris
30037
Dec. 30, 1896

A generator is fitted at the bottom with a screw which can be turned by a crank, the whole being placed at the top of a closed water reservoir. Carbide falls into the water on turning the crank. A purifying apparatus is used.

Generating Acetylene.

Schumacher, J.
Chicago
30134
Dec. 31, 1896

A generating chamber to contain the carbide and having a water inlet. Means for introducing a regulated quantity of water. Means to separate the lime from the carbide so as to arrest when necessary the generation of the gas, and means for keeping the water and carbide apart when the carbide and residue are separated.

Producing Acetylene.

Trendel, F.
Micke, J.
Berlin
139
Jan. 2, 1897

Carbide in a porous form is presented to the water in such a manner that it always offers to the water a large free surface of contact with but slight depth. The contact takes place from the bottom and gradually rises.

Producing and Burning Acetylene.

Zimmerman, J.
Chicago
328
Jan. 5, 1897

Water is admitted to the carbide automatically. A vessel is provided with a liquid-holding chamber, a generating and a gas-retaining chamber. Means are also provided for the automatic admittance of water to the generating chamber. An automatic pressure regulator on a pipe connected with the

generator and gas chamber is employed, located in the retaining chamber. Means are also provided for regulating the diaphragm of the pressure-governor to any desired tension.

Producing Acetylene.

The carbide is revolved in a cage while water is projected on to it, so the waste lime falls away from it. The cage is made to revolve by clockwork. The supply of water is governed by the movement of the bell of the gasholder.

Lebrun, G. Cornaille, F. Paris 512 Jan. 7, 1897

Producing Acetylene.

Two concentric cylinders communicate at their base, the inner being surmounted by a carbide receptacle with a valve closing the bottom, which is opened or closed by a float connected with the rod of the valve. Carbide is allowed to fall into water in the inner cylinder, when the gas drives the water from the inner cylinder and the falling float closes the valve of the carbide supply. With diminution of pressure the water flows back, the float rises, and more carbide is allowed to fall.

Tédé, L. Angers 658 Jan. 9. 1897

Producing Acetylene.

A generator is attached to the side of a displacement gasholder, the upper part of generator being connected with the service pipe, whilst a pipe below the level of the carbide leads to the top of the holder. The gas is passed through a condensing coil in the water tank.

Holliday, T. Huddersfield 885 Jan. 12, 1897

Producing Acetylene.

An intermittent or continuous working apparatus. The supply of water to the carbide is regulated by syphons. A water compartment in the centre of the generator washes and cools the gas. The gas bell controls the supply of water to the carbide.

Daix, V. Paris 911 Jan. 13, 1897

Generator.

Automatic evolution of acetylene at constant pressure is claimed. Two vessels, one for carbide the other for water, are used, being connected with an intermediate chamber.

Des Essards, E. H. Paris 1153 Jan. 15, 1897

Generating Acetylene.

A square shaped gasholder is used, the tank having extended sides at the top to hold any surplus water. The outer wall of the gas bell is perforated at the lower end to allow of free circulation of water between bell and tank. Centrally supported within the bell by a flanged head is a circular generating chamber, in which the carbide is placed in cages. The generation of gas withdraws the carbide from the water, owing to the rising

Moss, R. J. Abingdon 1254 Jan. 18, 1897

of the bell, and as the gas is consumed the carbide again dips into the water with the fall of the bell.

Generating Acetylene.

Fuller, H. F. **Chicago** 1440 Jan. 19, 1897

The carbide is supported in successive layers. A condenser and cooler, in the character of a scrubber, are provided. Special attention is paid to the arrangement of the charging manhole to prevent leakage.

Cycle and similar Lamps.

Clarke, H. B. **Chicago** 1421 Jan. 19, 1897

The carbide chamber is at the bottom of the lamp, and is separated from the water chamber above it by a diaphragm with a passage through it. The water in the water chamber is permitted to pass through a valve to the carbide chamber when the gas pressure falls below a certain point, and when the pressure rises above this point the valve closes and the water supply is cut off. In one form the valve is actuated by a spring pressing upwardly to close it when the gas pressure is high, and the weight of water in the water chamber to open it when the gas pressure falls. In another form of lamp a piston is worked against a spring to control the position of the valve.

Acetylene Furnace.

Sterza, A. **Mantova** 1549 Jan. 20, 1897

A device for mixing acetylene with air for heating purposes. The gas is passed through several wire and asbestos cloths placed inside two concentric vessels.

Generating and Burning Acetylene.

Gobron, A. **Paris** 1784 Jan. 22, 1897

The water is supplied automatically, according to consumption of gas. The pressure is regulated by a safety valve, the excess of gas passing to a supplementary burner. The burner tap is connected with the water feed, so that the tap must be opened before water can attack the carbide.

Producing Acetylene.

Thorp, T. **Marsh, T. G.** **Manchester** 1929 Jan. 25, 1897

By the movement of a gasholder carbide is automatically fed into water, the rise of the holder stopping the supply of carbide. The gas is taken through the carbide hopper, there being dried.

Generating Acetylene.

Scott, A. M. **Woodstock, Canada** 1952 Jan. 25, 1897

Two generators are fixed at the side of a gasholder, and contain a water sprinkler over a tray for carbide, the bottom of tray sloping towards a hydraulically sealed pipe. The gas passes through a condensing coil to the holder. The bell of the holder picks up a weight on reaching a certain height ; pressure accumulates, and causes the driving back of the water supply from the carbide.

Production of Acetylene.

Colophony and caustic lime are subjected to the action of water or acidulated water, and the produced gas mixed with the gas evolved by the action of water upon a mixture of carbide and magnesium carbonate. The addition of magnesium carbonate is to render the flame more luminous.

Piatti, A. and Co.
Rome
2129
Jan. 26, 1897

Producing Acetylene.

The generator containing a large charge of carbide is provided with an agitator to remove the lime. Means are provided for the automatic admission of a certain quantity of water when the supply of gas falls too low.

Carter, R. F.
Niagara Falls
2284
Jan. 28, 1897

Generating Acetylene.

The production of gas is automatically regulated according to the consumption. Two holders are used, connected with each other by a non-return valve.

De Sales, G.
Lyons
2292
Jan. 28, 1897

Generator and Condenser.

A modification of a previous patent. A chamber is attached to the floating gas vessel, sealed by water at the lower end, and by a suitable cover at the top. An annular container is also used for holding any overflow of water displaced by the working of the apparatus.

Bean, H. R.
Ringwood, H.
London
2428
Jan. 29, 1897

Generating Acetylene.

A water reservoir is placed over the generating chamber, so that the water cannot freeze owing to the heat of the action, the steam being condensed upon the under side of the tank. The water vessel and generator are connected by a capillary regulator, so that the pressure of gas in the holder governs the water supply.

Villejean, E. G.
Frossard, H
Paris
2554
Jan. 30, 1897

Producing Acetylene.

Crushed carbide is fed into water from a holder fixed to the top of a gas bell, the feed being regulated by two cones actuated by the movement of the bell, the fall of the carbide being divided into two successive periods.

Macé, P.
Gerard, L.
Paris
3013
Feb. 4, 1897

Portable Lamp.

A small generator for a table or bracket lamp, consisting of an upright standard, with two tanks arranged thereon, connected by a passage. One tank contains water, the lower part of the other the carbide.

Dennis, W. H.
Minneapolis, U.S.A.
2976
Feb. 4, 1897

Producing Artificial Light.

Wigham, J. R. **Dublin** 4125 Feb. 16, 1897

Acetylene generator for lighthouses. Within a cylindrical water tank is a cylindrical receptacle with openings in its bottom edge and a horizontal perforated partition half-way up for the carbide. Surrounding the inner receptacle is an inverted funnel, having holes around its lower edge and a suitable valve and gas outlet.

Producing and Burning Acetylene.

Gossart, E. Chevallier, H. **Fampoux** 4424 Feb. 18, 1897

Improvements on a previous patent. The carbide is attacked by drops of water from above, and by the moisture in the evolved gas from below. The water drops fall on a cone which distributes them to the carbide. Under the lower end of the escape pipe is a cone for distributing the condensed water to the carbide. The water from the capillary tubes falls on a cone to the carbide at the bottom. The water receiver is closed at the top by metallic gauze. The walls of the generator are coated internally with black cloth or felt, to prevent condensation of water vapour. The carbide container is surrounded by an air jacket.

Generator.

Lacroix, P. M. **Toulouse** 4761 Feb. 22, 1897

In the generator carbide is placed in a series of baskets. Water is supplied from an overhead tank, the generator being connected with a fixed gasholder. The pressure of gas regulates the supply of water.

Acetylene Lamp.

Smith, F. H. **Dunblane** 4790 Feb. 23, 1897

Two chambers, water in top, carbide in bottom. Water chamber contains coiled pipe through which gas passes on its way from carbide chamber to burner. A small tube conveys water from the water reservoir to the carbide chamber. A valve, from which the water drops upon the carbide, is fitted over the mouth of this tube, and as the pressure of gas increases, the valve closes and stops the water passage. As the pressure is relieved the valve again opens.

Generating and Burning Acetylene.

Franco Carlos, B. **Barcelona** 5236 Feb. 26, 1897

Claims the separation of water needed for the decomposition into two reservoirs connected by a tube; the entrance of moisture to the carbide by utilising some absorbent substance; the mode of drying, condensing, and enriching the gas; a fixed or portable gasogene, in which the water comes in contact with the carbide, after passing through a porous partition.

Producing Acetylene.

Upon the rise of pressure within the gasholder, the water is automatically cut off, and upon further rise of pressure all free water round the carbide is discharged. The apparatus consists of a combined water tank and gasholder, a generator, a displacement cistern, suitable valves controlled by a float within the water tank for closing the water supply pipe, and a water pipe fitted with non-return valve between the generator and water tank.

Baldwin, G.
Crastin, C.
Holloway
5445
Mar. 1, 1897

Generator.

An outer water vessel, an inner gasholder, a perforated carbide holder, and a receptacle for waste lime. The charging chamber is placed in the centre of the gasholder, and fixed to the top of it.

Bean, H. R.
Ringwood, H.
London
5756
Mar. 4, 1897

Producing Acetylene.

A carbide holder divided vertically into several compartments, which only communicate with one another at the upper end, so that water will act on each successively. The water is drawn from the gasholder tank, and the amount regulated by the movement of the bell.

Alexandre, H. E.
Barcelona
5913
Mar. 5, 1897

Generating Acetylene.

The supply of water to the carbide is automatically regulated in proportion to the gas consumption; the supply also can be automatically increased during the exhaustion of gas from the holder. The thickness of the gasholder wall is so graduated that the amount of water displaced as the gas leaves the holder, owing to the falling of the holder, bears any desired ratio to the amount of gas withdrawn, the sides of the holder being tapered, so that the displacement of water by the holder when full is not sufficient to generate any gas, a greater proportion of water being supplied as the holder falls.

Strode, W. W.
White, G. H.
London
6658
Mar. 13, 1897

Generating Acetylene.

Steam instead of water is used for the decomposition of the carbide. Regular evolution of gas at a low temperature is claimed.

Pereire, G.
Sorel, E.
Paris
6997
Mar. 17, 1897

Generators.

An apparatus for preventing the escape of gas during the operation of charging. A tank or cistern has a bell free to rise and fall, having a hole at the top, through which is passed a cylindrical vessel, inside which is a perforated carbide holder. The apparatus is in duplicate.

Lyons, T. and J.
Pearson, J.
Blackburn
7043
Mar. 18, 1897

Generating Acetylene.

Gesellschaft fur Acetylen Gaslicht Bale 7744 Mar. 25, 1897

A generator with movable bottom, provided with safety valve and pressure gauge, surrounded by a cooling vessel, a gasholder, and a water vessel. A five-way cock is provided in the water supply pipe to the generator.

Acetylene Generator.

Ferracciù, F. Italy 7782 Mar. 25, 1897

A gasholder is supported on a tripod, and a generator is clamped to the bottom of the gasholder, and connected with the tripod. The generator contains four small movable baskets, each with a central tube suitably perforated, so that water descending from a funnel on the top basket first moistens the carbide in the lowest basket. The space within the gasholder bell is nearly filled by an impermeable drum attached to its crown, and serving as a float. The acetylene evolved causes the float to rise, and when the bottom of the float has reached the level of the water in an external basin, the supply of water to the generator is automatically cut off.

Generators.

Kitchen, J. G. A. Manchester 7918 Mar. 27, 1897

Portable generators. A gas-tight vessel to contain water, having a hollow base containing a flexible collapsed chamber communicating with the vessel, and a perforated carbide holder loosely fitted into the vessel. The excess of water is forced by pressure into the rubber chamber, thus stopping the evolution of gas.

Generator.

Smith, F. H. Dunblane 7929 Mar. 27, 1897

The water supply to the carbide can be stopped without the use of a valve. An upright cylinder is divided horizontally, the upper part forming the water reservoir, the lower the generator. The upper chamber is divided into two portions; a pipe from one leads to the bottom of the lower. Leading to the carbide chamber from this is a pipe slotted in the upper part. Water rises to the height of this slot and then passes to the carbide chamber. The gas is led off to a holder. After a certain pressure the gas forces the water from the lower chamber into the upper, till the water level is below the slot.

Generators.

Kitchen, J. G. A. Manchester 8270 Mar. 31, 1897

The water is led to the carbide by means of a wick-tube passing from a lower vessel and fitted with a feeding wheel. Granulated carbide is preferably used, and as it is decomposed it is pressed by a springed plate on to a grating, when the lime is separated from the carbide, and the gas produced is forced through the remaining carbide.

Manufacturing Acetylene.

An automatic arrangement, consisting of a hopper supplying granulated carbide, a device for regulating the supply of carbide, a gasholder, a generator containing water, and a purifier. **Cousin, H. Paris** 8552 Apr. 3, 1897

Producing Acetylene.

Two generators are used, the second being automatically brought into action on exhaustion of the first. They are mounted one on each side of a gasholder, in the upper part of which is a condensing coil for the gas. The pressure of gas automatically regulates the supply of water. Any number of generators may be coupled together by pipes leading from the top of the first to the bottom of the next, and so on. **Exley, J. H. Huddersfield** 8551 Apr. 3, 1897

Producing Acetylene.

A base plate carrying four carbide holders, and capable of revolving. Water from an overhead pipe falls on the carbide in one receptacle, and on exhaustion the plate is swung round to bring the next holder under the water supply. **Kerr, J. G. Fry, C. Niagara Falls** 8989 Apr. 8, 1897

Producing Acetylene.

A receiver divided into two compartments, the inner forming the generator supplied with water by a side **U** tube. Within this compartment is a float, carrying a conical carbide holder with a grid base. The outer compartment, with a gas bell, forms the gasholder. The bell slides with slight friction upon a central vertical carbide shoot, and the bell, in rising, actuates a weight in connection with the carbide hopper, carbide dropping into water as the holder sinks, and the supply being cut off as the holder rises. **Barthez, A. H. Algiers** 9294 Apr. 13, 1897

Producing Acetylene.

The carbide is automatically fed into a vessel containing water from a distributing drum divided internally into several compartments with movable bottoms. Each charge of carbide falls through a funnel on to a trap which opens at the proper time to allow the charge to fall into the water. The movement of the gas bell regulates the supply of carbide. **Kesselring, U. St. Imier** 9714 Apr. 15, 1897

Portable Generators.

The upper chamber contains carbide, the lower vessel contains water. The carbide chamber has a hinged gas-tight lid, and an orifice at its base. Upon one side of the carbide chamber is a groove into which is fixed a rack, and the groove is sufficiently wide to permit a pinion to travel up and down. The pinion is mounted upon a spindle, which can be rotated by turning a milled head. By this arrangement the carbide vessel may be **Kitchen, J. G. A. Manchester** 9763 Apr. 17, 1897

raised or lowered. The water vessel contains a piece of sponge or other absorbent material saturated with water. To generate gas the carbide chamber is lowered until its bottom orifice is in contact with the wet sponge. To stop generation the chamber is raised.

Acetylene Lamps.

Hutton, E. K. and W. Selkirk 9857 Apr. 20, 1897

A cylindrical generator composed of two parts screwed together and divided by a horizontal plate into upper and lower chambers. The upper chamber is filled with water, and the lower chamber has a screwed socket on its bottom, within which is fitted a perforated holder for carbide. A tube conveys water from the upper chamber to the lower, the pipe being provided outside with a cock for regulating the flow of water. From the lower chamber a tube is carried through the water in the upper chamber, and the gas is conveyed from this tube to the lamp by a flexible tube. The water chamber is provided with a safety blow-off tube.

Acetylene Generator for Lamps.

Crastin, C. and Baldwin, G. London 9928 Apr. 20, 1897

In a suitable water reservoir a number of generator chambers adapted to be hermetically closed are placed. These chambers receive perforated pots charged with carbide, and are provided with openings to provide communication with the reservoir. The openings are closed by valves adapted to be independently operated to permit of admitting water into them in succession. The upper part of the reservoir serves as a gas storage space, to which each generating chamber is connected by a pipe fitted with a non-return valve. This gas space has an upward extension forming a pedestal for a lamp and containing an extensible bellows, which is collapsed when no gas is in the apparatus, and which expands and drives out the air from the space above it into the atmosphere, when gas is generated. Similar bellows may be arranged in each generating chamber to displace the air. If the gas pressure becomes excessive, the gas which continues to be generated can escape into a supplemental chamber by the displacement of water. The carbide pots are placed on flexible seatings around openings in communication with a waste-water tray.

Generating Acetylene.

Morency, D. C. Quebec 10186 Apr. 23, 1897

The carbide is placed in a vessel contained in a tank covered by a bell made gastight by a hydraulic seal. An inner wall in the bell prevents the water coming in contact with the carbide. Attached to the carbide holder is a gasholder containing brine or solution of calcic chloride or oil or molasses. Water is

supplied to the carbide from the gasholder tank, and the supply is cut off automatically by pressure of gas.

Producing Acetylene.

The carbide is placed within and in connection with a moving gas bell, so that the carbide is immersed as the bell sinks, but rises out from the water as the holder rises.

Deutsche Acetylen Gesellschaft Berlin
10199
Apr. 23, 1897

Acetylene Lamps.

Portable acetylene lamps, with special reference to the regulation of the water supply to the carbide and the escape of gas from the generator, also for keeping the generator cool without cooling the evolved gas.

Deutsche Acetylen Gesellschaft Berlin
10249
Apr. 24, 1897

Generating Acetylene.

Water is admitted to the first of a series of carbide trays, and when the carbide is exhausted the water overflows to the next container, and so on. Provision is made for re-charging the rest whilst the last container is in use.

Evans, E. Llanrwst
10508
Apr. 27, 1897

Generating Acetylene.

The generation of gas is regulated by the rise and fall of the gasholder. Arrangement is made for cutting off the water supply should the holder sink too far on exhaustion of the carbide. Another modification employs two or more generators brought into action automatically and successively.

Patterson, J. J. Batavia, U.S.A.
10686
Apr. 29, 1897

Generator.

A stationary cylindrical generator in which is a perforated shelf. Beneath the shelf is a central tube communicating with other tubes with the outside of generator. The cover forms a safety valve with discharge pipe in centre. The whole is inserted in a larger cylindrical vessel.

Sutcliff, H. Halifax
11644
May 11, 1897

Generator.

The generator is attached to the side of a gasholder and partly filled with water. The carbide is contained in a receptacle above the generator, and allowed to come in contact with the water by the rise and fall of the holder.

Campbell, C. H. Philadelphia
12120
May 15, 1897

Producing Acetylene.

The tap between the generator and gasholder is controlled by the movement of the gas bell. A safety syphon is provided for escape of surplus gas. The water is taken from the gasholder tank.

Trouvé, G. Paris
12110
May 15, 1897

Producing Acetylene.

Preston, A. Atherton
12263
May 18, 1897

A ball valve and float operated by the gasholder bell admits water to the carbide. A back pressure valve is employed in the upper end of the pipe, which conveys the gas to the holder to prevent escape of gas during re-charging. A purifier is also used.

Producing Acetylene.

Quatannens-Moens, R. Carreer Dilger, E. Belgium
12556
May 20, 1897

The water supply to the carbide is controlled by pressure of gas in the generator. A reserve generator is employed during the re-charging. The generator is provided with a cooling water jacket, and is supplied with water from a tank, the valve being controlled by the movement of a float in a second tank immediately below the main tank. A purifier containing sulphate of iron, on top of which is a layer of chloride of calcium, is used.

Generating Acetylene.

Dresser, F. Liverpool
13081
May 27, 1897

A vertical partition divides a vertical cylinder into two compartments, one closed at the top, forming a gas chamber, and communication between the two being established through a hole at the bottom of the partition. A slanting grid is placed in the second compartment, which is open at the top. The vessel is filled with water, and carbide introduced in a bag of canvas, and falling upon the grid is borne into the closed chamber. The gas generated forces water out of this chamber into the other.

Generator.

Mitchell, F. A. Wilmington, U.S.A.
13496
June 1, 1897

The generator is fitted at the side of a gasholder, the supply of water being regulated by the movements of the gasholder. An alarm is arranged to indicate the exhaustion of the carbide, and a force pump is attached to remove the remaining acetylene from the generator to the holder.

Acetylene Gas Plant.

Whalley, D. Hacking, J. Ideal Gas Co. Blackburn
13667
June 3, 1897

The claim is the arrangement of pipes connecting the generator with the condenser and condenser with the gasholder. Water cannot rise as high as the bend of the pipes, so that neither water from the tank nor water of condensation are carried forward with the gas.

Production of "Oxycarbene" Gas.

Soxhlet, F. Van den Berghe, F. Borremans Frères Hal, Belgium
13905
June 5, 1897

Carbide is automatically fed into water by the rise and fall of the gasholder. A certain quantity of air is first admitted to the holder, so that when the holder is full it contains a mixture of air and acetylene. A regulator and "flame arrester" of rolled metallic gauze are placed at every burner.

Producing Acetylene.

Several carbide holders are used, the water acting on each successively. The carbide boxes float on the water, engage with a trip device, and are overturned into the water, or they are provided with hinged bottoms, opened at the proper time by a float, allowing the carbide to fall into the water, or the boxes are balanced on ledges at different heights, so that the rising water overturns them, emptying their contents into the water.

Trendel, F.
Berlin
14015
June 8, 1897

Holders for Gases.

Through a tube wholly or partly capillary water falls drop by drop on to a lower vessel containing carbide. The pressure of the gas is regulated by the pressure of the water on the gas.

Jimeno, E.
Barcelona
14090
June 9, 1897

Production of Acetylene.

A gasholder containing bellows, arranged in such a manner that when expanding or contracting they leave room for the gas in the holder, or take the place of the gas. The pressure is regulated by a weight.

Jimeno, E.
Barcelona
14091
June 9, 1897

Generating Acetylene.

A perforated carbide holder is placed in a cylindrical vessel, a space being left between the sides and bottoms, thus allowing condensed water to be drawn off without attacking the carbide. The carbide chamber is surrounded by a water jacket in connection with two cisterns placed one above the other. The water for the carbide is taken from the cisterns, the lower of which is completely filled with water. The gas passes through the upper cistern, any excess being stored in the lower, and cutting off the water supply to the carbide.

Haviland, F. H.
Murch, W. H.
Bournemouth
14208
June 11, 1897

Generating Acetylene.

The carbide holder is placed in the gasholder bell, and can be charged from the exterior. On the holder sinking the contents of the box are automatically tipped into the water, and as the holder rises it is closed air-tight, so that the box can be changed at leisure. A two-chambered exit box is provided for the gas, one filled with sponge and the other with asbestos.

Gaskell, G.
Reeve, R. F.
Liverpool
14313
June 12, 1897

Generating Acetylene.

The carbide vessel with an air-tight lid is placed in a cylindrical vessel. The pressure of the gas controls the water supply, which rises to the carbide from below. The gasholder is divided into two chambers, the upper double wall containing the bell, and the lower containing a purifying chamber fixed to the partition. This chamber is filled with water to supply the carbide, and through it the gas passes by a coil to the purifying chamber, and is thence drawn off for use.

Fowler, T. R.
Liverpool
14742
June 18, 1897

Producing Acetylene.

Macé, P.
Paris
14905
June 19, 1897

5 to 15 per cent. of manganese dioxide is proposed to be added to the mixture of lime and carbon for the electric furnace. The two carbides produce a mixture of methane and acetylene, which will burn without smoke.

Generating Acetylene.

Scarth, J. W.
Pudsey
15125
June 24, 1897

A generator is fixed to the side of a gasholder. When the bell sinks a displacer causes water to overflow to the lower part of the generator to attack the carbide. The rising of the bell stops the supply of water. Means are also provided for driving the water back from the carbide and for preventing escape of gas during re-charging.

Generator.

Smith, F. H.
Dunblanc
15754
July 2, 1897

An apparatus for the automatic supply of water to the generators successively. The generators consist of a divided chamber, a pipe leading from the bottom of the upper to the bottom of the lower chamber, in which there are two or three slotted tubes, the central tube having a slot at a higher level. In it are also recesses in which carbide trays are placed. A five-way cock regulates the water supply, and the exhausted carbide vessels may be re-charged without interfering with the rest.

Generating Acetylene.

Ayckroyd, J. and B.
Culling-worth
16344
July 10, 1897

A water vessel divided into two chambers is used. In the upper is a bell, and to the chamber is attached a generator. The exit pipe for the gas passes above the water level and then down to the bottom of the lower chamber. The water pipe for the carbide is a syphon with a water seal having a valve normally closed, but opened by the fall of the bell.

Acetylene Lamps.

Zimmerman
16624
July 13, 1897

In the base of the lamp is a circular block of carbide surrounding a vertical perforated tube. The upper circular portion of the lamp is an annular water chamber. The flow of water to the carbide chamber is controlled by a cock or valve. An open pipe conducts the gas to the burner from the carbide chamber. The burner is provided with a movable needle for cleaning. A safety valve is provided.

Generating Acetylene.

Sigurdsson, O. V.
Hammer-smith
16793
July 15, 1897

Carbide is placed in a hopper, at the bottom of which is a feeding chamber with an opening communicating with the supply chamber and another with the generator. A two-way valve can open to the supply chamber or the generator. The motion of the rising bell first shuts off the supply of carbide to

the generator, and then opens the way between the hopper and feed chamber, the operation being reversed as the bell falls.

Generating Acetylene.

Two generators working successively are attached to the top of a tank divided into two chambers, the upper receiving the gas, and the other, which is in connection with the first, containing a ball float valve, a discharge pipe, and a gas delivery pipe. Water under pressure rises to the carbide from below. Gas, water, and lime then flow into the first tank, where the two latter remain whilst the gas passes to the second chamber. The excess of water is discharged through the ball valve in the second compartment. The water supply to the carbide is governed by the gas pressure.

Bowers, A. F.
Paris
16975
July 17, 1897

Generating Acetylene.

The carbide holder is attached to a vessel open at the bottom, and supported in the lower part of a cylindrical tank of water. The pressure of gas controls the water supply to the carbide.

Godin, E.
Quebec
17021
July 19, 1897

Generating Acetylene.

The carbide is suspended in a vessel in the top of a gasholder, and comes in contact with the water when the bell sinks. A special device is claimed for preventing excess of gas generation.

Barnard, E.
Christchurch
17090
July 20, 1897

Generating Acetylene.

The generator is connected to the holder, and above it is a device for tipping a measured quantity of water into the generator when the holder sinks. As the holder rises any excess of water from the tipping tank runs to waste. An improved condensation chamber and safety valve are also claimed.

Carter, R. F.
Niagara Falls
17448
July 24, 1897

Generating Acetylene.

Claims: The automatic regulation of the water supply by a floating body or spring. The successive exhaustion of the carbide in several generators. The closing of the generators by means of lids, so as to render the apparatus odourless. And the use of the pipes for withdrawing condensed water as safety valves for excessive pressure.

Reggiani, N.
Chrisini, A.
Rome
17482
July 24, 1897

Generating Acetylene.

Porous material, such as felt, is placed between the water and the carbide, and the regulation of the rate of percolation is provided for by compressing the material. The carbide holder is placed in a tank of water, the base of the holder being rounded so that excess of pressure will drive the water from the carbide.

Kitchen, J. G. A.
Manchester
17793
July 29, 1897

The porous material is placed in a small gland at the lower side of the carbide holder.

Portable Lamps.

Kitchen, J. G. A.
Manchester
17794
July 29, 1897

The bottom of a water reservoir is fitted internally with a layer of felt or similar absorbent material. In the top of the reservoir is a neck screwed to receive a collar, which encircles a long tube containing carbide, and fitted at the top with a stopcock and burner. The bottom of the carbide tube is in contact with the felt pad, and by means of the collar in the neck of the reservoir can be adjusted to press loosely or tightly upon the pad. The bottom of the tube is provided with a small orifice and rim facing. The rate of flow of water through the pad to the carbide is dependent upon the degree of compression which the carbide tube exerts upon the pad.

Generating Acetylene.

Rieffel, A.
Paris
17938
July 30, 1897

A water tank discharges intermittently into a basin, from which the feed pipe for the carbide water supply is taken. The generator contains the carbide placed on shelves. Chief characteristics: a combined tank and basin to ensure constant water level in the feed pipe; a rising and falling pipe conveying water to the generator; the device for allowing for the varying weight of the holder acting on the water supply; and a condenser filter filled with canvas or similar material kept constantly wet.

Generating Acetylene.

Goulding F.
Great Harwood
18128
Aug. 3, 1897

The supply of water is regulated by the movement of the gas bell. A back pressure valve is used to prevent escape of gas into the water pipes.

Generating Acetylene.

Josse and Defays
Lille
18355
Aug. 6, 1897

Two or more generators are used, in which the carbide is placed in shallow trays resting on one another. A gasholder and water tank in connection with the generators through a special mercury valve operated by the gas bell, and a washer or purifier are also employed.

Acetylene Generator.

Bull, J. C.
Erith
18355
Aug. 6, 1897

Two or more generators charged with carbide are connected with each other and with a gasholder, the water being supplied to the generators, and controlled through the medium of a mercurial valve actuated by the movement of the gasholder bell. The mercurial valve is situated upon the outer side of the gasholder tank, and consists of a vessel adapted to contain water having another vessel containing mercury suspended

within it, and an open tube connected with the water-tank and dipping into the mercury. The inner vessel is suspended by means of a spring-controlled rod, which is depressed by a stop on the gasholder bell when the latter falls to a certain position. When the bell rises the spring forces the rod into its normal position, and prevents water flowing to the generator until the bell again descends. The orifices of the water pipes are situated at or near the top of the generators, but downward curved flanges are provided to prevent the water from splashing upon any carbide except that contained in the lowest unattacked tray. One generator may be cleaned out while the other is in action.

Portable Generator.

Denich, A. Paris 18907 Aug. 16, 1897

A metallic cylinder having its ends closed, and composed of two parts which screw into one another, is provided. The upper part, which serves as the water reservoir, is divided from the lower part, which forms the carbide holder, by a horizontal partition having an opening for the passage of water. The water regulator forms the main feature of the invention. It is composed of a socket secured to the bottom of the water reservoir, communicating by a small passage with the carbide chamber, and in which is introduced a piston. The piston is secured to the end of a rod, which, passing upward through the water reservoir, enters a collar socket screwed on another socket outside the top of the reservoir, terminates in a button. The collar socket has five notches, one above the other, in one of which is hung a pin which passes through the rod. Inside the reservoir a spring passes around the rod. By turning the button the height of the notch in which the pin is placed, and consequently the rate of flow of water, is regulated.

Generating Acetylene.

Wigham, J. R. Dublin 18971 Aug. 17, 1897

Water is supplied to the carbide stored in cylindrical vessel with movable divisions from a vessel of equal capacity at a higher level. The generating cylinder is sealed with a mercury lute, so as to dispense with the use of screws, etc., for fixing the cover. Washing vessels and a purifier are provided.

Generating Acetylene.

Barnard, E. Christchurch 19319 Aug. 20, 1897

As the bell of the holder sinks, carbide is fed from a sealed receptacle on the top to a perforated basket suspended in the bell. An arrangement is provided for withdrawing the spent carbide from the basket.

Generating Acetylene.

Bell, H. J.
Niagara Falls Co.
19411
Aug. 23, 1897

A generator previously described is provided with a screw top instead of a water-sealed top. Improvements in the method of introducing measured quantities of water to the generator and other minor points are claimed.

Generating Acetylene.

Munsterberg, O.
Berlin
19615
Aug. 25, 1897

The bell of the gasholder actuates an endless band provided with ledges to hold carbide, thus automatically feeding carbide into the water. Means are provided for storing excess of gas in a second holder, or allowing it to waste.

Generating Acetylene.

Thorp, T.
Marsh, T. G
Manchester
19823
Aug. 28, 1897

Granulated carbide is fed into water from a hopper, through a valve actuated by the movement of the gas bell. The hopper is divided into two by a flap valve. Carbide is placed in the upper part, the lid put on gastight, and the valve opened by a crank from without, when the carbide falls into the lower chamber ready for use.

Generating Acetylene for Lighting Boats, Auto-cars, etc.

Chambault, L.
Paris
19951
Aug. 30, 1897

A casing is divided into two parts, the upper forming the water reservoir, and the lower containing the basket charged with carbide. Upon one side of the basket is a stopping box fitted with an internal baffle plate. This box serves as a regulator, and receives the water from the upper reservoir through a pipe provided with a stop-cock. Water drops through a nipple upon the carbide in the basket, and the gas escapes to the burner through a tube in the partition which divides the casing. Excessive gas pressure prevents flow of water to the carbide. Several modifications in size, shape, and form of the generating arrangement all working on the same principle are described. In one form the generating device is fitted within a walking-stick, and the burner is lodged in the top of the stick.

Acetylene Generating Lamps.

Rhind, F.
Bridgeport, U.S.A.
20052
Aug. 31, 1897

Refers to portable lamps.

Generating Acetylene.

Rhind, F.
Bridgeport, U.S.A.
20051
Aug. 31, 1897

A vessel is divided into two parts, the lower containing water, and the upper carbide in a bag. A central hole is made in the partition. Water is drawn by a wick, moved from outside by a rack and pinion till it comes in contact with the bag of carbide.

Generating Acetylene.

The carbide holder is automatically shaken by a special device, in order to expose fresh surface to the water and to get rid of spent material. This is done when the gas pressure falls below a certain point, when water is admitted, the increase of pressure causing the rotation of the cylinder.

Dolan, E. J.
Philadelphia
20011
Aug. 31, 1897

Generating Acetylene.

The carbide hopper is fixed on top of the gas bell, and has a valve attached to a float. When the holder falls the float causes the valve to open, thus admitting carbide to the water, and *vice versâ.* The level of the water in the tank is kept constant by an overflow tap.

Kieffer, F. A.
Paris
20142
Sep. 1, 1897

Portable Generator.

A tube is divided by a gas-tight removable diaphragm into two chambers, the upper to contain water, the lower carbide. In the centre of the diaphragm is a conical opening, which is controlled by a conically pointed plunger having a spindle, which passes through the cap of the water chamber. The point passes through the conical opening, and forms a cleaner for the opening, and also acts as a drip point for the water. A regulating valve may be provided to control admission of water to conical valve. The gas is led from the bottom of the carbide to the burner by a pipe passing through the base of the tube. A spiral slot in the conical plunger allows any gas which may accumulate under abnormal pressure when the water valve is closed to escape through a valve, and through the water, and into the air.

Windham, F.
London
20537
Sep. 7, 1897

Generating Acetylene.

See patent No. 5756 of 1897. Three vessels containing carbide in communication with the interior of the bell are attached to the inside top of the bell at different heights.

Bean, H. R.
Ringwood, H.
London
21114
Sep. 14, 1897

Acetylene Lamp.

The outer cylindrical casing, which serves as the water reservoir, is closed at the top by a screw plug carrying the gas outlet cock and the air-inlet valve. Within this is a second cylinder having its lower end closed with a metal plug pierced with a central perforation, and its upper part fitted with a tube of small diameter, which leads to the gas outlet cock. In this inner cylinder is placed a perforated tube or basket which serves as a carbide holder, and has a cock attached beneath its base to prevent blocking of the perforation in the metal plug. Water being introduced into the outer cylinder, it flows through

Chardin, C. E.
Paris
21372
Sep. 17, 1897

the perforation to the carbide, and when the generation of gas becomes more rapid than the consumption, the water is forced back by the gas pressure from contact with the carbide.

Cycle Lamp.

Windmuller, J.
Cologne
21464
Sep. 18, 1897

A cycle lamp, the upper part serving as a water reservoir, the lower provided with a double wall containing the carbide. The pressure of the gas forces the water out of contact with the carbide.

Cycle Lamps.

Wizard Co.
Chicago
21831
Sep. 23, 1897

A stick of carbide is pressed against an absorbent pad, to the under side of which water is admitted from a surrounding water receptacle.

Generating Acetylene.

Ageron, J. A.
Wirth, L.
Paris
22648
Oct. 2, 1897

The gas produced by the fall of carbide into water passes through a pressure regulator, the supply of carbide being regulated by the movement of the gas bell. Each burner has a central delivery tube for the addition of oxygen or ozone.

Generating Acetylene.

Flock, A.
Messedat, F.
Cologne
22730
Oct. 4, 1897

A chamber is divided into four parts—a water reservoir, a carbide chamber, a chamber connected by a perforated plate with the carbide, and a drying chamber containing pumice soaked in sulphuric acid. Water from the reservoir passes through the perforated plate to the carbide, the gas passing through the drying chamber to the exit pipe. Pressure of gas forces the water back from the carbide through the third chamber, and thence to the first.

Generating Acetylene.

Beck, C. W.
Chicago
22850
Oct. 5, 1897

Objects: to provide means for maintaining a regulated supply of liquid to the carbide, to provide a relief reservoir for excess of gas, and a means for charging the generator without escape of gas.

Portable Acetylene Lamps.

Bailey, C. J.
22918
Oct. 6, 1897

The carbide is contained in a small cylinder, which has a central tube not quite reaching to the top of the cylinder. This central tube is surrounded by a tube of perforated metal or wire gauze. At the upper end of the cylinder is fitted another cylinder, the bottom of which may form the top of the first cylinder. The second cylinder contains water, and is fitted at its lower end with an outlet and escape valve or tap, and a pipe which leads to the lower end of the central tube in the first cylinder, and which may contain a back pressure valve. A small vent is made in the top of the water cylinder. When

water is admitted from the upper cylinder to the carbide cylinder, it rises in the central tube of the latter, and flows over its upper edge to the bottom of the space enclosed by the perforated tube. It then flows to the carbide, which is packed around the outer side of the perforated tube.

Generating Acetylene.

The bottom of the carbide box is slightly inclined, the downward motion of the carbide towards the water being started by a vibrating hammer actuated by mechanism. The water reservoir is divided into two parts, communicating by a pipe. The hammer is regulated by a float within the water reservoir. Increase of pressure causes the water level to sink, and interrupts the movement of the hammer.

Molet, A.
Buenos Ayres
23198
Oct. 9, 1897

Generating Acetylene.

A carbide hopper is fixed to the top of the generator, having a feeding chamber at the base communicating with the hopper and the gas generating chamber, the valve opening and shutting off the carbide supply being operated by a forked lever engaging with a stud on the gasholder.

Sigurdsson, O.
Hammersmith
23351
Oct. 11, 1897

Generating Acetylene.

A series of generators, supplied with water from an overhead cistern, are connected with a gasholder. Two generators are worked together whilst the others are shut off. Each generator is divided into radial chambers, so arranged that the contents of each shall be successively attacked by the water. A three-way cock between the washer and generator allows excess gas to be blown off. The water supply is governed by the rise and fall of the holder.

Wartenweiler, A.
Spengler, R.
Switzerland
23547
Oct. 13, 1897

Generating Acetylene.

Water is supplied to the carbide through a small pipe ending in a spray. The tap of the water supply has a weighted lever arm for closing, whilst the arm on the other side is connected by a chain to the bell of the holder, causing automatic addition of the water to the carbide.

Buffington, L. S.
Minneapolis
23802
Oct. 15, 1897

Acetylene Generators.

Seven carbide cylinders, open at top and closed at bottom, but connected in such a way as to form triangular tubes between each, are contained in a larger cylinder, which in turn is introduced into another containing receptacle. Water from an upper tank, having a constant water level, enters the lower part of the generator, and passes through a hole in the bottom of the first carbide cylinder. The gas produced passes consecutively

Guadaguini, P.
commonly known as
Johnson, W.
London
23977
Oct. 18, 1897

through the top of all the carbide cylinders. After the water has flooded the first cylinder, it overflows and descends to the bottom of the second cylinder, and so on in succession. Accumulation of gas pressure forces back the water from contact with the carbide. A small floating bell, or a displacement gasholder may be used, but the claims include the abolition of the ordinary gasholder. Several modifications are described.

Generating Acetylene.

M'Conechy, J.
Glasgow
24301
Oct. 21, 1897

Three generators connected to a gasholder, each consisting of an upright casing with dome-shaped top, the opening of which is closed by a lid. The upper portion of the casing contains a water tank, from which water falls on the carbide. The amount of water is just sufficient to decompose the carbide.

Acetylene Lamps.

Holliday, T.
Huddersfield
24360
Oct. 21, 1897

A perforated cage in the bottom of the lamp contains carbide. The water reservoir at the top of the lamp is provided with an external device to manipulate the valve which regulates the flow of water through the tube which leads from the water chamber to the carbide. Between the water and carbide chambers is a chamber to serve as a gas container, from which the gas passes through a porous filter to the burner. The gas container is provided with a gas safety valve. In some cases a rubber ball is employed for storing the gas.

Acetylene Generator.

Heal, J. B. and S. H.
Southsea
24446
Oct. 22, 1897

Two drawers, having perforated bottoms and containing carbide, are passed into corresponding horizontal cylindrical generating chambers having arched roofs, and the doors are closed. The chambers are themselves situated within a closed water displacement tank, the bottom of each chamber being in communication with this tank. By manipulation of various cocks water is allowed to rise in the tank until it enters the chambers and reaches the carbide. The gas liberated forces back the water until it flows into a water level-maintaining tank situated behind the water-displacement tank, and at about the same level as the carbide drawers. The displacement tank is connected with a gasholder, the bell of which is so loaded that it will not rise until the gas pressure exceeds that exerted by the normal height of water in the level-maintaining tank. The surplus gas collected in the gasholder passes into the displacement tank and is consumed before the water can return to the carbide.

Generating Acetylene.

A carbide receptacle and a vertical gastight elastic pouch are fitted to the gastight lid of a water reservoir. By means of springs and levers the elastic pouch, after being filled with acetylene, prevents the fall of the carbide into the water, whilst when the pouch collapses the carbide can fall into the water. The pouch is so arranged that inflation occurs chiefly in the side connected to the lever arrangements.

Guy, C.
Ivry
24707
Oct. 25, 1897

Generating Acetylene.

The carbide falls into water from a hopper, the movement of the bell acting on an endless band always worked in the same direction.

Ravel, L.
Marseilles
25002
Oct. 28, 1897

Acetylene Lamps applied to Tubular Frames of Bicycles, etc.

The generator consists of a tube within which is placed a removable tube charged with carbide. At the lower end of the carbide tube is a screw-cap pierced with a small hole for the water inlet. The upper end of the carbide tube carries a tubular extension, whose external surface is made to tightly fit the interior of the vertically inclined tube of the cycle frame. One or more holes are made at the junction of the carbide tube with the extension, communicating from the exterior of the carbide tube to the interior of the extension tube. In the top of the carbide tube is a small gas discharge pipe carried nearly to the top of the extension tube, and there furnished with a tap and a nozzle to receive a flexible pipe. The flexible pipe is connected to another tube, preferably of metal, which is carried in the horizontal tube of the cycle frame to a gas tap and nozzle on the steering post, from which the gas is led by another flexible pipe to the lamp. The lower end of the vertically inclined cycle tube is hermetically sealed, but is provided with a cock and outlet for cleaning purposes. This vertically inclined tube itself serves as the water reservoir, a side inlet furnished upon the outer side with a removable safety valve being provided.

Bond, E. S.
Handsworth
25189
Oct. 30, 1897

Generating Acetylene.

Improvements on a previous patent. The carbide tube is continued for a short distance below the surface of the water in the generator, and terminating in a distributing cone. This prevents the acetylene coming in contact with the distributing basket wheel, and avoids any escape of gas during charging.

Barthez, A. H.
Algiers
25870
Nov. 6, 1897

Generating Acetylene.

Acetylene Light Syndicate Trowbridge 25952 Nov. 8, 1897

Two generators successively brought into action automatically. The water supply is controlled by the movements of the gas bell.

Generating Acetylene.

Alexandre, F. Paris 26325 Nov. 11, 1897

The carbide generator is arranged in the upper part of a fixed gasholder, together with a water reservoir. The carbide cylinder is water-jacketed, and rests upon the porous bottom of the surrounding cylinder, forming a bell for the generated gas. Water passes to the carbide through holes closed by porous partitions. The pressure of gas regulates the supply of water.

Generating Acetylene.

Arkell, G. E. Bailey, J. Clapham, J. Keighley 26269 Nov. 11, 1897

The water used for washing the gas is afterwards used for generating the gas. Three generators are fixed at different levels, together with a regulator. The gas passes through this regulator to the holder, which, rising, transmits motion to the valves. These motions cause the intermediary vessel or regulator to be kept supplied with a regular quantity of water, through which the gas passes, and which is afterwards employed to decompose the carbide.

Generating Acetylene.

Mucke, J. and J. Berlin 26435 Nov. 12, 1897

Under the dome of a gas bell, carbide holders are arranged at different heights. The gas is forced, by means of a bell covering the carbide holders, through the milk of lime. The water supply tank has a lever arm controlled by the movement of the bell.

Acetylene Lamps.

Hall, R. F. Birmingham 26614 Nov. 15, 1897

The carbide may be placed directly in a metal cartridge, which is then hermetically sealed; or it may first be sealed up in a porous envelope of fabric or unglazed paper, and then transferred to the metal cartridge, which is subsequently hermetically sealed. If desired, the cartridge may have an air-tight removable cover.

Acetylene Lamp.

Schmid, F. Vienna 26676 Nov. 15, 1897

The upper part of lamp contains water, the lower contains carbide placed in a removable holder. The carbide is covered by a disc of felt. The water passes through a specially constructed valve. The rate of flow of water from the upper reservoir is dependent upon the degree of compression exerted upon a disc of felt or cloth placed therein. The water passing through this regulator drops upon the felt which covers the carbide, and which is not compressed. The carbide receptacle

may be divided into compartments to come into use consecutively, and the water supply may be diverted from one compartment to another by aid of a funnel having one or more spouts, which may be turned by a rod passing to the outside of the casing.

Generating Acetylene.

The lower part of the bell of a gasholder supports a coned sieve on which the carbide falls. Fixed to the tank, but rising within the bell, is the carbide hopper, and externally on the bell is another hopper from which the inside one may be filled, by means of a cock, even while the apparatus is at work. The movement of the bell operates the valve which regulates the fall of the carbide into the water.

Kremer, J.
Belgium
26776
Nov. 16, 1897

Acetylene Lamps.

Generator resembles a bicycle pump and is clipped to any suitable part of cycle frame. It is a long tube closed at base and having screw cap at top. Through this cap passes the gas eduction tube and a valve to act as an air regulator. The carbide holder in the lower part of the tube contains a series of superposed trays threaded upon a central tube, by which all the trays may be removed. Water from the outer tube flows through a piece of sponge at bottom of carbide holder, up through a perforated tube and an outer slit tube to the carbide. Increase of gas pressure forces back the water from the carbide.

Evans, E.
Denbigh
26810
Nov. 16, 1897

Converting Ordinary Lamps into Acetylene Lamps.

Oil lamps and candle carriage lamps are provided with suitable air-inlet holes, ventilation holes, acetylene burners, and gas supply pipes terminating in a nozzle to receive an india-rubber pipe. The acetylene may be delivered to the flexible tube from any form of generator.

Bond, E. S.
Handsworth
26842
Nov. 17, 1897

Generating Acetylene.

Carbide holders are attached to the side of a gasholder. They are water-jacketed, and their water is supplied from the holder tank. To the top of the holder are attached rods which operate on the cogs of a crank by means of which the water supply is regulated.

Benjamin, J.
Swansea
27065
Nov. 19, 1897

Generating Acetylene.

Carbide falls in fragments one by one into water, the rate being controlled by the bell of a gasholder. The carbide is fed to the discharge pipe on an endless band.

Reibel, J.
Angouleme
27288
Nov. 20, 1897

Generator.

Schulke, J.H.
Berlin
27767
Nov. 25, 1897

In a water tank several generators are placed, each communicating with a gas-pipe leading below the water tank to a weighted gasholder, the tank of which contains a condensing coil. The carbide vessels are open at both ends and perforated. Each fits into a cylinder open at the top and surrounded by a bell, into which the water flows, but its height is determined by the pressure of gas in the bell. By means of a pipe the water is supplied to the carbide from below.

Acetylene Lamps.

Roxburgh, A. B.
27689
Nov. 25, 1897

The bottom chamber contains carbide, the top water. The water for the carbide is supplied from an intermediate chamber, which is in communication with both water reservoir and carbide chamber in such a manner that when water passing from the intermediate chamber through a tube to the carbide generates sufficient gas to create an increasing pressure, then the gas escapes to the top of the intermediate chamber and exerts its pressure on the surface of the water until it has driven the water below the level of the opening of the supply pipe, the retreating water being forced up into the top chamber. A small compartment located in the top water reservoir filled with cotton-wool serves to filter the escaping gas on its way to the burner.

Generating Acetylene.

Liver Acetylene Gas Co., Ltd., Liverpool and Evans, E. Denbigh
27876
Nov. 26, 1897

Improvements of Patent No. 10508 of 1897. The carbide trays are all placed in a tray-holder closed at bottom, but having a vertical channel passing up one side of the chamber. Into this channel water can enter from outside through a hole near the top, and this water can escape through a guarded hole or series of holes connecting the channel with the tray chamber, and so arranged that water entering the hole at top runs down to bottom or to level of water in tray chamber instead of spurting through at once. Also in order to allow the air in the gas bell to escape when it is lowered into its tank, a siphon is fitted in the gas bell, with its open end opening into the top of the bell, and its bend descending nearly to the bottom. The other limb is carried upwards to a point above the bell, where it is provided with a hole to allow air to escape when the bell is lowered into the tank. This hole is sealed when the water has risen in the bell to above the height of the open end, and remains permanently sealed.

PATENTS FOR ACETYLENE GENERATORS

Generator.

The bell of a gasholder carries a tube sealed by the water in the tank, down which carbide is dropped, falling upon the cone-shaped base of the tank, the cone preventing it falling directly below the feed tube. Four types of generator are illustrated.

Tyree, W.
New Zealand
28094
Nov. 29, 1897

Acetylene Lamp.

A tube with three superposed compartments; the bottom contains a perforated cage charged with carbide, and the intermediate contains water. The top compartment is a purifier. Water passes to the bottom of the carbide chamber by a pipe controlled by a cock. The carbide chamber is also in communication with the purifier, which has a feed water pipe extending through it to the water chamber. The top of this feed tube is provided with a funnel closed by a screw-plug having a minute aperture through it. The aperture admits such air as is required for the automatic working of the lamp, and acts as a safety valve in event of excessive gas production. The purifier contains "special chemicals" placed upon a rose.

Wagner, M.
France
28102
Nov. 29, 1897

Acetylene Lamp.

The carbide chamber forms the base of the lamp, and is supplied with water from an upper reservoir mounted at the back of the lamp. The tube communicating between the two chambers contains a porous wick, which passes nearly to the bottom of a perforated tube which rises centrally in the carbide chamber. The perforated tube is surrounded with fine muslin. The gas produced passes through a filtering medium up a central tube to the burner. Accumulation of gas pressure retards the flow of water through the wick. A stopcock or valve is also provided to regulate the flow of water.

Keck, L. J.
Liverpool
28258
Nov. 30, 1897

Acetylene Lamps.

The carbide holder is a cylinder with minute holes drilled at short intervals up the side, and capped or corked at the ends. This is placed within a cylinder having a minute hole in its base, and a cap at its upper end with a small tube for carrying the gas to the burner. This cylinder, together with the carbide holder, is enclosed in a larger cylinder which serves as a water reservoir and has a screw cap at both ends, the upper cap having in its centre a hole to allow the gas tube to pass through and to act as a safety valve in the event of the gas pressure within the apparatus becoming excessive.

Chitty, J
London
28167
Nov. 30, 1897

Acetylene Generator.

Grubb
Sir H.
Dublin
28264
Nov. 30, 1897

A generator, provided with baskets or compartments and charged with carbide, is connected with an elevated water tank, so that water will flow naturally to the carbide. The gas passes into a displacement holder, the increase of gas pressure forcing the displaced water up a pipe into the water supply tank, and leaving the generator comparatively dry. The generator may be provided with a water-jacket, and the closing of the various valves when it is necessary to recharge may be automatically performed by removal of the cover of the generator. The valves are preferably operated by springs. Several modifications in the arrangement of plant working on this principle are described.

Producing Acetylene.

Sockeel, V.
Lanby, A.
Drisse, C.
Calais
28439
Dec. 2, 1897

The carbide is placed in the upper part of a vessel divided by a perforated diaphragm, milk of lime falling into the lower. The carbide vessel is placed within another truncated cylinder, the whole being placed in the tank of water. After being purified the gas passes into a gasholder.

Generating and Purifying Apparatus.

Richard, B.
Lyons
28798
Dec. 6, 1897

An automatically closing gasholder, the closure being disposed within the gas bell. A generator consisting of three chambers, one containing the carbide in cages, and another acting as a purifier. A drying chamber. An automatic water-feed. A top valve, which may be automatic or worked by hand. A safety device, consisting of a bell moving in a mercury seal.

Making Illuminating Gas.

Bryant, H.
Texas, U.S.A.
28824
Dec. 6, 1897

Two tanks are provided, one being furnished with a movable bell, and the other being of any suitable form and capable of withstanding a high internal pressure. The vertical cylindrical generator, containing a removable carbide holder, is connected to both the rise-and-fall gasholder and the high-pressure tank. The latter tank has near the top a diaphragm, above which is a water reservoir, a water inlet, and a pipe with a valve for feeding water to the generator. By lifting this valve water is allowed to flow into the generator. The gas, by lifting a valve, escapes to the burners in use, and if generated faster than it is consumed, the excess gas passes into the movable gas bell. The bell rises and lifts a chain, which actuates a lever and cuts off the supply of water to the carbide. If the generation of gas still continues excessive, then the excess gas would pass into the pressure tank and is stored there without increasing the

gas pressure at the burners. The fall of the gas bell allows the gas in the pressure tank to escape and water to again flow to the generator.

Generating Acetylene.

Crushed carbide drops into water from a conical hopper, the supply being regulated by a valve, which acts as a measure and distributes the carbide, and is actuated by a float.

Boule, E. M.
Versailles
29054
Dec. 8. 1897

Portable Generator.

A capillary tube is slit longitudinally to receive a strip of blotting paper or similar absorbent material. The tube may also be perforated and surrounded with wick. The tube is centrally placed in the cylinder charged with carbide, so that it extends from its base almost to its cap. The carbide cylinder being placed in a tube fixed in a receiver containing water, the water will enter the lower end of the capillary tube, ascend the strip of blotting paper, and moisten the carbide. The gas is led from the cap of the carbide tube to the burner. Increase of gas pressure drives the water from the capillary tube.

Prevost, E. V., Rans, O., and Cerkel, A.
Paris
29201
Dec. 9, 1897

Acetylene Lamp.

The carbide holder is a cylindrical vessel situated in the middle of the lamp body. It terminates at the bottom in a cone, having a circular opening adapted to be closed by a rubber ball. Above the carbide holder, and in communication with it, is a drying and purifying chamber. Water is poured into the lamp through an orifice (having a screw stopper) at the top, the carbide holder having previously been introduced through a screw-cap opening at the base of the lamp. The carbide holder is covered by a fixed bell, and the lamp body is divided into two compartments. When water is poured into the lamp it rises in the body and in the bell until it reaches the rubber ball, which it lifts, and then comes in contact with the carbide. When the gas pressure rises it forces back the water out of carbide holder, and presses the ball on to its seat. The gas generated after the closing of the valve, if it cannot escape by the burner, is compelled to pass through a tube to the water below the division plate in the lower part of the lamp. Here it makes a gas chamber for itself by forcing back the column of water, until allowed to escape through the burner.

Bergmann, F. J.
Germany
29258
Dec. 10, 1897

Generators.

A small water-tube, containing a thread or wire to increase its capillarity, ensures the regular feed of water to the carbide.

Marechal, V.
Garcin, L.
Paris
29405
Dec. 11, 1897

Acetylene Gas Producer.

Thiersant, H.
Coulson, W.
London
29571
Dec. 14, 1897

The carbide holder placed below communicates with an outer vessel containing water by means of curved pipes. Round the holder is a gallery, a number of small holes allowing communication with the holder. The two are covered by a cone-shaped vessel fitted with pipes. Water only comes in contact with the carbide when the pressure falls below a certain limit.

Producing Acetylene.

Smith, F. H.
Newcastle-on-Tyne
29843
Dec. 16, 1897

A number of packages containing carbide are placed at the bottom of a vessel containing water, and are automatically and successively opened so as to admit water. Instead of separate packages of carbide, a tray having several compartments charged with carbide and covered with tinfoil may be employed. In the water chamber is a float fixed to a vertical spindle free to rise and fall and to turn in bearings. When the pressure of gas decreases, the level of water rises, and with it the float, and a knife or perforator suitably attached thereto perforates one of the carbide packages or chambers. Increase of gas pressure depresses the level of the water, and with it the float, and thereby raises the knife. The float carries a pin which rotates between two toothed wheels to effect movement of knife from one chamber or package to another.

Generating Acetylene.

Wagner, M.
France
29960
Dec. 17, 1897
Cl. July 13, 1897

For industrial purposes it is necessary to supply the acetylene under a pressure of 20 centimetres to a metre or more. Therefore an apparatus is constructed in which water flows from an elevated tank to a generator containing compartments charged with carbide in such manner that the charges are attacked successively. The generator and purifier are entirely surrounded with water. The pressure of gas in the generator is regulated by the length of pipe between water supply reservoir and generator, the flow of water being stopped when the gas pressure is sufficient to equalise the pressure of this height of water column. A feed water cylinder for the supply reservoir is also provided. The purifier is charged with a mixture of sulphate of copper, sulphate of iron, and sawdust.

Generating Acetylene.

Baughan, W. H.
Charbury
30272
Dec. 22, 1897

Two tanks to be filled with water are provided, one to contain a gasholder bell, the other to contain one or more vertical cylindrical carbide chambers. The gasholder tank contains a condenser and an automatic water supply valve, and the two tanks are connected by suitable pipes, and filled with water to the same level. The supply of water from the gasholder tank

to the carbide chambers is automatically cut off when the bell rises, and re-connected when the bell falls to a certain position. The carbide is contained in perforated trays, and the water first attacks the carbide in the bottom tray. One generator can be cleaned while a second is in action.

Producing Acetylene.

The water supply is regulated by a lever operating taps, and depending upon the movement of the bell of a gasholder. As the holder rises the water is cut off by a spring working a quadrant.

M'Conechy, J. Glasgow
30585
Dec. 28, 1897

Acetylene Lamps.

Water is sprayed over carbide. The carbide chamber is at bottom, and water reservoir at top. An intermediate gas and water chamber is connected to both top and bottom chambers in such a way that water flows into the intermediate chamber and down a pipe to the carbide sprayer, until the pressure of gas which escapes to the top of the intermediate chamber is sufficient to force the water back until it is below the entrance of the supply pipe. The retreating water escapes to the upper tank until the pressure is relieved. Several carbide chambers, to work singly or simultaneously, may be provided. The carbide holder has a perforated bottom, and a drain into which the waste water may collect. The parts may be arranged to form either a vertical or a horizontal generator.

Ritchie, J. Smethwick
30602
Dec. 28, 1897

Acetylene Generators.

The carbide is placed in receptacles made of finely woven fabric. The receptacles should be only partially filled.

Mücke, J. and J. Berlin
30637
Dec. 28, 1897

Acetylene Generator.

A cylindrical tube is filled with water, and in its lower part is immersed a closed cylindrical carbide holder. The carbide holder has a perforated tube extending from its lowest internal end to a stopcock situated just below its top cover, and terminating in a short pipe, which passes through the cover, and thus allows water to flow into the carbide holder through the perforated tube when the stopcock is open. The handle of the stopcock passes through the side of the carbide holder and also through the side of the outer cylinder, so that the cock can be operated externally. Two tubes also extend from the top of the carbide holder to the exterior of the cover of the water cylinder. One is the gas eduction tube, and terminates in a stopcock; the other is a safety tube, and terminates in a safety valve.

Legge, J. C. and Cooper, A. S. Dublin
30690
Dec. 28, 1897

Generating Acetylene.

Barnard, E. **Christchurch, Hants** 457 Jan. 7, 1898

Within the bell of a gasholder a perforated bucket is suspended. As the bell descends, a charge of carbide is delivered from a hopper attached to the outer top of the bell into the bucket. Small quantities of carbide are thus automatically distributed to the water, and withdrawn by the rising of the bell to a certain height. A long rod extends from the false bottom of the carbide box down towards the bottom of the gasholder tank, so that when the bell sinks sufficiently to cause this rod to touch the bottom of the tank, carbide is pushed out of the supply box and falls down a shoot into the bucket. Several modifications of this arrangement are described.

Cycle and Carriage Lamps.

Barnard, E. **Christchurch, Hants** 490 Jan. 7, 1898

Claims the use of the tubes of bicycles or other vehicles for containing acetylene or other gas generating apparatus.

Acetylene Lamps.

Richardson, S. T. **Birmingham** 891 Jan. 12, 1898

Two cylindrical vessels are connected side by side: one contains carbide, the other water. The pipe connecting the lower ends is fitted with a small cock to regulate supply of water to carbide. At the top the cylinders are connected by a small tube fitted with a cock that opens simultaneously with the lower water cock, so that gas from the carbide cylinder flows to the water cylinder and equalises the gas pressure on the water. A branch pipe from this top tube leads down to the burner. Each cylinder has a removable cover, and the cover of the water cylinder may be pierced with a hole, in which is fitted a small tube leading down nearly to the bottom of the cylinder to admit air if required.

Acetylene Generator.

Bournonville, E. **Jersey City, U.S.A.** 1013 Jan. 13, 1898

Carbide is fed in certain quantities into water automatically by the descent of the gas bell. The carbide is covered with oil to prevent atmospheric decomposition, this oil also forming a layer on the water in the tank.

Producing Acetylene.

Macé, P. P. H. and Burgue, J. de **Paris** 1005 Jan. 13, 1898

A long cylindrical vessel divided horizontally at about its centre, but so constructed that the two parts can be fitted gastight into one another. The cover of the upper portion carries two threaded orifices, in which are screwed two rods threaded at their upper ends. The bottom of this upper portion also carries two tubular orifices through which the water, which is contained in the upper chamber, passes to the carbide in the

lower chamber. By screwing down the two rods which terminate in cones, these orifices can be closed. The carbide is contained in a removable cylinder provided with small orifices. It is closed at its lower end by a movable bottom, to the centre of which is attached a tube which rises vertically in the cylinder, and has a lateral opening at its lower part. The top of the carbide cylinder also carries a perforated cover having a central tube which fits into the larger tube rising from the bottom. Some of the water falling upon the perforated cover attacks the top layers of carbide, while a further portion falling down the central tube attacks the bottom layers.

Acetylene Generator.

Drummond, J. **Aberdeen** 1154 Jan. 15, 1898

Two generators containing carbide are situated at the side of a gasholder, the bell of which rises and falls in an oil seal. The water, which falls from an overhead tank, is cut off from the working generator by the rise of the bell. The generators work alternately, one being recharged while the other is in action. The carbide holder in each generator rests in a water sealed space, and fresh charges of carbide can be inserted without removing the spent charge or stopping the manufacture of gas until the holder is filled with spent material. A slide valve is provided for automatically changing the supply of water from one generator to the other.

Portable Lamps.

Kitchen, J. G. A. **Manchester** 1477 Jan. 19, 1898

Water passes from the upper reservoir through a cock and a regulator, and then along an absorbent wick to the carbide in the base of the lamp. The regulator is an arrangement for compressing the wick more or less by means of an adjustable screw, so that the flow of water along the wick may be regulated.

Acetylene Lamp.

Davison, A. C. and Lucas, H. **Birmingham** 1549 Jan. 19, 1898

The carbide chamber is detachably connected with the base of the lamp. The water reservoir is at the top of the lamp and is connected to the carbide chamber by a suitable pipe, through which is passed a screwed stem valve which controls the water supply. The valve seat passes through a fixed conical plate separated from a lower movable conical plate or cup by means of a spring. The water drops upon the lower plate and reaches the carbide by flowing over the periphery. The products of gas combustion are led away by a flue tube passing through the water reservoir in a direct vertical line with the burner beneath.

Portable Lamps.

Thiersant, H. Coulson, W. London 1584 Jan. 20, 1898

The carbide holder is placed in a vessel provided with an escape valve. Water attacks the carbide through a spiral perforated tube.

Manufacturing Acetylene.

Owens, W. Pontardawe 1625 Jan. 20, 1898

Water is automatically supplied to carbide by the movement of a gas bell, which engages a lever opening a valve between the water supply and the carbide. The carbide is placed in trays in the generators, the water rising from below. A condensing chamber with baffle plates is used.

Producing Acetylene.

Quatennens-Moens, R. Carreer-Dilger, E. Belgium 1665 Jan. 21, 1898

The generator containing water is surrounded by an annular tank and connected to a gasholder. The carbide is in charges in a distributing drum immediately above. A valve opens when a charge of carbide falls on it, allowing the charge to fall into the water, and closes immediately. The distributing drum is worked by the movement of the gas bell.

Generators for Lamps.

Arnot, M. C. New York 1760 Jan. 22, 1898

The generating chamber is attached to the bottom of the lamp, and is provided with a charge of carbide preferably in the form of a disc. A smaller block of carbide is fastened to the lamp bottom immediately above the generating chamber, and is just below the opening which admits the acetylene to the burner. An auxiliary water receptacle is situated between the lamp bottom and a false bottom above it, while the main water tank is an annular chamber situated on the top of the lamp. When the valve in this upper water tank is opened, water runs into the lower auxiliary water vessel and causes an overflow into the generating chamber. The acetylene, generated after being dried by the upper block of carbide, passes to the burner. When the gas is generated too rapidly, the accumulation of pressure forces back the water and prevents its further flow until the pressure decreases.

Acetylene Generator.

Moss, R. J. Birmingham 1920 Jan. 24, 1898

Improvement on a previous patent. Means are provided for trapping the gas in the generator to prevent escape of gas during recharging of the generator.

Acetylene Lamps.

Holliday, R. and Holliday, R. & Sons Hudders-

Water is conveyed to the carbide by a wick, the entrance of the wick to the carbide chamber being at a higher level than that of the water. The carbide chamber is immersed in a vessel containing water, and the portion of the wick which

descends into the carbide can be opened out amongst the carbide. The other portion of the wick passes out of the carbide chamber and down a vertical tube into the water. A valve is provided which can be screwed down upon the wick to check or stop the flow of water.

field
2078
Jan. 26, 1898

Acetylene Lamp.

Goodwin, J. S. London
2714
Jan. 27, 1898

The carbide receptacle is a tube provided at the top with a removable cap, and terminating at the bottom in a truncated cone perforated centrally. The upper cap is also perforated centrally, and is provided with a gas outlet pipe extending upwards through a tube in the upper part of the lamp, and around which is stored the water for decomposing the carbide. The carbide receptacle is placed within a larger cylinder, having the water reservoir at the top, and fitted at the bottom with a removable cap and washer. The bottom of the carbide receptacle is fitted with a handle, the lower end of which rests upon the washer at the base of the cylinder. A horizontal partition above the carbide receptacle separates the water chamber from the lower part of the cylinder, save that a very narrow pipe extends from the water chamber nearly to the bottom of the cylinder, through which water is allowed to slowly rise to the carbide.

Acetylene Generator.

Jacobi, G. Dresden
2309
Jan. 28, 1898

Carbonic acid gas from a cylinder of the liquefied gas forces water out of a vessel into the generator, the supply of the carbonic acid gas being regulated by stopcocks.

Producing Acetylene.

Thorp, T. Whitefield
2454
Jan. 31, 1898

See a previous patent. The improvements regulate more perfectly the supply of carbide from the lower hopper to the generator, facilitate access to the admission valve without necessitating emptying the gasholder, and improve the construction of the filtering apparatus and washer.

Acetylene Lamps.

Praag, D. J. van and Harker, F. W. London
2227
Jan. 31, 1899

The carbide container has a number of separate compartments communicating at bottom with each other. The lower part of container has a pressing plate and spring to keep the carbide in contact with moist pad of lime which forms at top of container. In another form of container the charge of carbide is divided into small portions by partitions. Water is allowed to drop upon the carbide, but the container and water supply nozzle are rotated relatively to one another, so that the water continuously drips upon a fresh surface of carbide. The rotation

may be effected by hand, or by rise and fall of a gas bell. The lamp comprises an upper water reservoir with an adjustable supply valve, and a lower part provided with a water seal forming gastight joint between the outer parts and a removable carbide container.

Generating Acetylene.

Marcks, H. O. Berlin 2602 Feb. 1, 1898

Charges of carbide attached to rods are caused to fall as desired into water.

Generator for Portable Lamps.

Beaumont, R. C. Rochdale 2534 Feb. 1, 1898

Gas is generated by the drip of water through a capillary tube upon carbide from a water vessel above it. The generating apparatus may be a portion of the lamp itself, or may be separate from it. A tube runs from the water vessel to within half an inch of the bottom of the carbide chamber, and has a valve or tap fitted on its upper part. On the lower end of the tube is a short length of indiarubber tube, having a transverse slit, and closed at the end by an elastic cap forming a sensitive valve, which acts automatically. Excess of gas pressure prevents flow of water. A perforated sleeve slides over the water tube, and serves to distribute the water evenly through the carbide. A purifying chamber, partially filled with a mixture of anhydrous copper sulphate and calcium chloride, is provided. A burner with a bottom screw, by which the rate of gas consumption can be regulated, is also claimed.

Acetylene Generator.

Ferguson, J. S. Minneapolis 2863 Feb. 4, 1898

A number of receptacles charged with carbide are placed in a chamber, each upon a horizontal shelf capable of swinging downward to a vertical position when a latch beneath each shelf is deflected. The chamber is charged with water to about one-third of its height. A ratchet wheel outside the chamber being turned one tooth, rotates a shaft, and causes one carbide vessel to be precipitated into the water. Acetylene flows to a gasholder bell until the carbide from the one receptacle is entirely decomposed. Then when the withdrawal of gas from the holder causes the bell to sink until it reaches a certain position, a pendant rod attached to the top of the bell engages the ratchet wheel and rotates it one tooth, so that another carbide receptacle is thrown into the water. Thus the production of gas is automatically carried on until all the carbide receptacles have been precipitated.

Acetylene Lamps.

The top of the carbide chamber is closed by a removable gas-tight cover carrying a burner in its centre. Beneath the bottom of the chamber is a small socket or recess in which may be placed a piece of sponge, or preferably a vertical perforated tube covered with absorbent fabric and reaching nearly to top of chamber. The rate of flow of water through this socket is regulated by a valve or cock operated outside the apparatus. The carbide chamber is immersed in an outer water reservoir.

Major, J.
Eccles
3147
Feb. 8, 1898

Acetylene Lamps.

Fitted within the open bottom of the generator chamber and extending up therein almost to the crown is an inverted sack or bag made of canvas or similar material, and having the edges of its mouth end turned backwards to overlap and lie around the outside lower edge of the generator. A water-regulating compression cap of rubber closes the lower end of chamber and bag, and is so arranged as to leave a part of the canvas exposed for direct contact with water, whilst compressing other parts of the canvas between itself and the walls of the chamber. Carbide is contained in the canvas bag, and beneath the carbide bag and generating chamber is a reservoir containing water. To stop generation of gas the chamber containing bag with carbide is bodily lifted until the exposed parts of the absorbent canvas are clear of the water.

Sanderson, W. A.
Birmingham
3228
Feb. 9, 1898

Acetylene Lamps.

The water reservoir is a vessel about six inches in length and three inches in width, and preferably of oval shape in cross section. The carbide cylinder is of almost equal length, but of smaller diameter, and is placed within the water reservoir. At the bottom of the carbide chamber, which is pierced with two holes, is a tube extending from the centre of the carbide chamber into the water reservoir. The cock which regulates the admission of water to the carbide through this tube is operated by a handle outside the top of the water reservoir. The top of the carbide cylinder is connected to a gas eduction tube and stopcock.

Rous, T.
Ardleigh
3594
Feb. 12, 1898

Producing Acetylene.

A large drum is horizontally divided into two compartments. The upper one is open to the air, while the lower is closed, save for two small orifices. The upper compartment contains a smaller tank, in which is contained the water for the carbide. The small tank is connected by a pipe to the lower end of a cylindrical generator. The generator contains suitable cages charged with carbide, which the water surrounds as it rises

Mitchell, T.
Oldham
3531
Feb. 12, 1898

from below. The large drum is charged with water until it has filled the lower compartment and risen some distance in the upper compartment. The gas passes from the generator to the lower part of the lower compartment of the drum, where it bubbles through the water, and accumulates until withdrawn for use. Too rapid generation of gas causes the water in the generator to be driven back from contact with the carbide. The water from the lower compartment of the drum which has been displaced by gas rises into the upper compartment.

Acetylene Lamps.

Harrison, G. H. **Birmingham** 3835 Feb. 16, 1898

The water is in an upper reservoir, and the carbide in a lower chamber. The sole claim relates to the use of a cane with its lower end covered with flannel or similar material. The cane is the medium for conducting the water from the upper reservoir in just sufficient quantity to generate only as much gas as is required.

Acetylene Generator.

Coulson, W. A. and Thiersant, H. de **London** 4129 Feb. 18, 1898

A carbide feeder, having several compartments and operated by clockwork or other suitable arrangement, is fitted upon the top of the holder bell. The water in the holder tank is covered with a layer of oil. When the bell rises to a certain height, it engages a portion of the clockwork mechanism and prevents the discharge of carbide. When the bell falls the clockwork mechanism may be relieved from the stop piece and again operate the feeder. The carbide falls down a shoot, passes through the oil layer, and arrives at the bottom of a split cylinder fitted vertically to the bottom of the holder tank.

Generating Acetylene.

Berger, H. **Berlin** 4113 Feb. 18, 1898

The carbide holders are grouped to form a column. Means are provided for preventing the escape of gas during recharging.

Manufacture and Treatment of Acetylene.

Allegemeine Acetylen Gessels-chaft **Berlin** 4446 Feb. 22, 1898

The carbide falls on the sloping plate in a water reservoir through a feed tube. A condenser formed of trays of wire gauze, containing chloride of lime with other materials as desired, is used. An odour may be given to the gas by passing it over amyl acetate or carbylamine. Means are provided for mixing the acetylene with oil gas if desired.

Producing and Purifying Acetylene.

Walker, H. **Dublin** 4352 Feb. 22, 1898

A vertical lead-lined generator contains a bucket in which is an agitator, which may be worked by hand or power. Pipes convey water to the carbide and the evolved gas to the purifier. Carbide and a dry acid, such as oxalic, is placed with chalk in

the generator. The purifier contains sulphate of iron, or copper filings and iron sulphate.

Acetylene Generators.

Crushed or granulated carbide is automatically and intermittently fed into water. A vessel of cylindrical shape has an inner cylinder concentric with it. The water into which the carbide is discharged is contained in the inner cylinder, while a gas bell slides in a water seal between the walls of the two cylinders. On top of the bell is a tap with a pipe projecting vertically upwards. An arm attached to the outer cylinder extends upwards and carries the carbide holder, which can rotate on pivots, and has a conical spout, the larger end of which is fixed to the carbide holder, and the lower end of which is fitted with a pipe projecting downwards. This pipe is connected to the pipe on the gas bell by a flexible tube. When the gas bell is empty of gas, the carbide falls by gravity from the carbide holder down this spout and into the bell; but when the bell rises it raises the spout, and thereby causes the carbide holder to partially rotate on its pivot. When the bell has pushed up the spout until it is nearly horizontal with the carbide holder, carbide will cease to fall. As the bell sinks carbide will again commence to fall through the descending spout or channel. Several modifications of the generator are described.

Ross, J. H.
Birmingham
4372
Feb. 22, 1898

Acetylene Lamp.

The body of the lamp is constructed of an inner and outer metallic shell having a space between them to serve as a water reservoir. This chamber preferably surrounds the burner. The base of the lamp forms a carbide holder and has two parts, one an exterior casing, the other a cup attached from the underside to the casing. The cup has a perforated bottom and contains carbide. The water supply pipe is a vertically suspended tube passing from the outlet valve of the water chamber downward to the centre of the carbide cup. Over the outlet end of this vertical tube is passed another tube having perforated walls and a closed lower end. Around the perforated tube absorbent fabric is wrapped. The water passes through this porous fabric to the carbide. The gas passes from the carbide cup to the burner.

Millward, H.
Birmingham
4614
Feb. 24, 1898

Acetylene Generator.

The carbide is in a drum rotating over a water tank, and set in motion by the descent of a gas bell. The drum is divided into compartments, each provided with a hinged lid on the periphery of the drum.

Scheidt, B.
Charlottenberg,
4739
Feb. 25, 1898

Acetylene Generator.

Moss, R. J.
Birmingham
4801
Feb. 26, 1898

See a previous patent. Special carbide cages from which the spent matter can easily escape are provided, and a carrier for the cages and generating chamber resting upon the holder, and capable of being lifted out of its position.

Acetylene Lamps.

Hviid, L. P.
Copenhagen
5498
Mar. 5, 1898

A funnel-shaped receptacle is closed at the bottom with a slightly convex india-rubber membrane provided with a small fissure. A little distance above the membrane is a grid supporting the carbide. The mouth of an india-rubber bag is fastened around the lower end of the funnel. The whole is contained in a metal cylinder provided at the top with a removable gas-tight cover, and closed at the bottom with a soldered plate. A ring of perforations around the lower part of the cylinder allows free play to the internal rubber bag. The gas eduction pipe attached to the cover is provided with a safety valve. A certain quantity of water is poured over the carbide, and then the cover is screwed on. Acetylene is generated, and the pressure of gas forces the water through the fissure in the membrane down into the rubber bag. Increase of gas pressure causes the rubber bag to expand, but the water being forced away from the carbide generation ceases, until, owing to consumption of the gas, the bag again contracts and forces the water back through the fissure to the carbide.

Gas Producer.

Dedecker, L. J.
Brussels
5538
Mar. 7, 1898

A generator, having an inclined base and provided with a carbide hopper, is fixed to the side of a gasholder, the supply of carbide being controlled by the movement of the gas bell.

Generating Acetylene.

Schluter, C. H.
Lindemann, C. L.
Hamburg
5594
Mar. 7, 1898

Carbide vessels are fixed on a frame, being pivoted and kept in a horizontal position by springs. As the level of the water in the tank rises, a float engages these springs, causing the carbide to be tipped into the water. Water ceases to flow into the generator when the gas bell rises, but flows again when the bell descends, causing the float to act.

Acetylene Generators.

Clayton, R. and Steward, H. B.
Stafford
5701
Mar. 8, 1898

Sockets are fitted upon the internal base of a gasholder tank and long tubes, open at the top, and containing carbide, are inserted vertically in them. The mouth of each tube is above the level of water in the holder tank. Upon the top of the holder bell is a second tank containing water. Pipes provided with cocks pass from the bottom of this water tank through the bell

to deliver water over the carbide tubes, a separate pipe being provided for each carbide tube. When a cock is partially opened, water trickles into one of the carbide tubes. Acetylene is generated, and the bell rises. When the carbide in all the tubes has been decomposed and the gasholder is empty, the bell is removed and the tubes are taken out, cleaned, and recharged. In place of the common water-supply reservoir, an independent reservoir may be provided for each carbide tube.

Generating Acetylene.

Vezin, R. and Owdry, A. **Paris** 5908 Mar. 10, 1898

The generator is a cylindrical vessel of water fitted at top to carbide discharge apparatus, and connected with a gasholder. As the bell of the gasholder rises, its tappet releases the end of a lever, and a valve closes the carbide discharge opening under the influence of a spring. The descent of the bell again causes the discharge of carbide. A syphon-like tube enables the necessary water for the supply of the generator to be introduced during the working of the apparatus after having discharged the carbide residue. The discharge is effected by means of an inclined passage at bottom of generator having a draining cock at end.

Producing Acetylene.

Smith, F. H. **Newcastle** 5941 Mar. 10, 1898

Carbide is packed in watertight packages, in which are small holes with wicks leading from the holes through the mass of carbide. The packages are thrown into water.

Acetylene Generators.

Percival, J. **London** 6006 Mar. 11, 1898

The rise and fall of the gasholder produces a variation of level in the water in the generator. The generating cylinders are placed outside the bell, but move vertically between the bell and the gasholder tank. Water attacks the carbide in each cylinder from below.

Acetylene Generators.

Steiner, L. **Roumania** 7070 Mar. 23, 1898

The carbide holder has several separate partitions, the perforated bottoms of which are arranged at different levels, so that the carbide charges may be attacked successively. The holder is suspended from the top of a bell, so that when the bell, which rises and falls in a tank charged with water, contains little or no gas the holder is immersed in water, and when the bell rises the carbide holder is drawn out of the water. The top of the bell is detachable, and carries a stopcock and gas eduction tube.

Acetylene Lamp.

Millward, H. **Birmingham** 7102 Mar. 23, 1898

The water reservoir is in the upper part of lamp, and preferably surrounds the burner. The detachable carbide chamber is at base of lamp. Between the carbide chamber and water

reservoir is a socket containing drying and filtering material, through which the gas passes before reaching the burner. The water passes through a regulating valve to an inverted T tube having its lower end near the bottom of carbide chamber, and perforated above and below, and covered with absorbent material, through which water reaches the carbide.

Producing Acetylene.

Daix, V.
Paris
7521
Mar. 29, 1898

A gasholder and automatic water supply. A generator arranged air-tight upon the bottom of the water tank or on the outside. Carbide baskets placed in a drawer containing several compartments, and used in succession. And means for leading water from the holder to the generator and gas to the holder.

Acetylene Lamps.

Limelle, A. E. A. P. de
Lyons
7655
Mar. 30, 1898

A cylinder, having a perforated carbide tube in its upper portion, and a water reservoir in its base. A wick passes from the top of the carbide down through its centre to the water in the lower reservoir. The gas escapes through the perforations in the carbide tube to the annular space between this tube and the outer cylinder, and rises to the burner in the top of the cylinder.

Generating Acetylene.

Straëhl, E. de
Réchard, A. and Devarenne, A.
Paris
7770
Mar. 31, 1898

A vertical cylindrical case, arranged to contain a perforated tube in which are superposed trays charged with carbide, is fitted centrally within the bell of a gasholder, the top of the case extending to the outside of the bell, where it is closed by a gas-tight removable cover. The water in the holder tank first attacks the carbide in the lowest tray, the bell rising and drawing the carbide from the water when the rate of generation exceeds that of consumption. At top of carbide case is a tube and stopcock, and a similar cock is connected with the top of the bell. The two cocks are connected by a pipe containing a number of interlaced springs to clear the gas in its passage to the burner of particles of water and other impurities.

Acetylene Lamps.

Bond, E. S.
Handsworth
7777
Apr. 1, 1898

The upper chamber contains water, the lower carbide. The water passes to the carbide chamber through a valve controlled by a screw rod passing upwards through the top of the reservoir. The water passes down a pipe which extends to the bottom of the carbide chamber. The carbide is contained in a removable cylinder perforated near the top with one or more openings in the same horizontal line. The openings are covered with porous

fabric. The water ascends around the carbide cylinder until it reaches these openings, when it flows to the carbide. The carbide is covered with a disc, and rests upon a disc in the bottom of a cylinder, the two discs being attached to a central vertical rod. The gas passes through a pipe carried through the centre of the water chamber up to the burner. Gas evolved under excessive pressure escapes into the air through a small chamber upon the top of the water chamber. The chamber contains cotton-wool and charcoal impregnated with a strong pleasant perfume.

Acetylene Generator.

A number of carbide receivers are arranged over a water receptacle. The carbide is automatically fed into the water by means of a conveyer screw, which is actuated by the movement of the gas bell. The carbide, in small charges, drops into a large volume of water.

Szepczynski, S de
Vienna
7838
Apr. 1, 1898

Acetylene Lamp.

A cylinder with screw caps on top and bottom. The cylinder is divided horizontally, the upper portion forming water chamber, the lower a carbide chamber. A holder charged with carbide is placed in the bottom of the carbide chamber immediately beneath a sprinkler, which is attached to a tube leading from the water chamber. In the upper part of the carbide chamber is a perforated purifier, through which the gas passes on its way to burner. A cock with two transverse bores extends along the partition between the two chambers, one bore for admission of water and one for exit of gas. When the cock is closed, any gas which continues to be generated escapes through a longitudinal bore to the open air.

Sohnel, A. E. R. and Zehner, A. R.
Hamburg
8030
Apr. 4, 1898

Acetylene Generator.

A generator attached to a fixed gasholder divided into two. Water from the lower chamber is led to the carbide in the generator. The generator is provided with a settling tank, which can be cleared out when the cover of the generator is raised.

Kelly, C.
Passiac, U.S.A.
8147
Apr. 5, 1898

Producing Acetylene.

A double casing constituting a water seal, in which a holder works, is fixed on top of a water reservoir. The carbide holder is placed on the reservoir at the side of the casing, the valve of which opens with the fall of the gasholder, allowing the carbide to fall into the water.

Grand, J.
Lyons
8382
Apr. 7, 1898

Acetylene Lamps.

Lewis, T. H. and Lux Syndicate, Ltd. London
7303
Apr. 7, 1898

The lower portion of the lamp is the carbide chamber and contains a number of tubes, in each of which a carbide cartridge is placed. Water flowing from the upper part of the lamp enters the lower part of the first tube, then overflows through an opening near its top and passes down a duct to the lower part of the second tube, and thus decomposes the carbide in each tube in succession. The casing of the cartridges may be vegetable gauze, stiff canvas, or cloth, or the cartridges may resemble gun cartridges. The carbide may be reduced to powder and mixed with Kiesulguhr or like matter.

Generating and Storing Acetylene.

Stott, J. Oldham
8439
Apr. 9, 1898

Water rises round carbide, and the gas is led through a condensing coil to a displacement holder. The carbide is placed on trays fixed on an upright rod in the generators. The pressure of gas regulates the water supply.

Automatic Apparatus for Producing Acetylene.

Lacroix, P. A. M. Toulouse
8565
Apr. 12, 1898

See Patent 4761 of 1897. The present invention consists mainly in the application of a hydraulic lever—with a water-feed independent of the gasholder—to the circulation of water in one or more generators of any kind.

Acetylene Generator.

Graetz, A. Berlin
8675
Apr. 13, 1898

Two generators, to work alternately, a water tank to supply water to the carbide, and a gasholder, the movement of which controls the water supply. The movement of the gas bell also causes the water supply to be transferred from one generator to another when the carbide in the one is exhausted and the generator is completely filled with water.

Generation of Acetylene.

Bowers, A. F. France
8825
Apr. 15, 1898

The main feature is the employment of an automatic pressure regulator, consisting essentially of a receptacle having elastic sides or a variable volume, so that the capacity of the receptacle can be increased to a certain extent by exerting a pull upon one point of its wall, so as to fill it with air or liquid by suction; the said receptacle when thus filled and released having the tendency to reassume its original volume, thus forcing the air or liquid, in proportion as the acetylene is consumed, at an adjustable and graduated pressure. In an acetylene lamp shown, the base of the carbide container rests upon a bellows. The interior of the bellows communicates with the water reservoir, which surrounds the carbide chamber. The external wall of the reservoir is adapted to turn freely, and carries a

number of pins capable of sliding into slots provided in a support. When the apparatus has been charged with carbide and with water, the generator is freed from its supports, and rests upon the bellows, which undergoes compression sufficient to force water through a distributor; increase of gas-pressure causes the level of the water to fall below the distributor, and water ceases to flow to the carbide until the gas pressure decreases. To stop the working of the lamp, the generator is again lifted on to its supports so that it no longer presses upon the bellows.

Acetylene Lamps.

The upper chamber contains water, the lower contains carbide. Between the two chambers is a two-bore stopcock terminating in a thumbscrew outside the lamp. By turning the stopcock, water is delivered to the carbide, and acetylene is simultaneously allowed to pass to burner. The carbide chamber is provided with a spring safety valve.

Fletcher, W. B. and Cutler, J. Birmingham 8800 Apr. 15, 1898

Acetylene Lamps.

Three superposed compartments, the top forming a water reservoir, the bottom a carbide chamber, while the intermediate chamber is in connection with both neighbouring chambers. The gas outlet is a pipe running from the top of the carbide chamber to the burner. A wick or capillary tube passes from a suitable height in the intermediate chamber down to near the bottom of the carbide chamber. An open pipe projects from the bottom of the water reservoir down towards the base of the intermediate chamber, and another open pipe leads from the top of the carbide chamber up through the water in both upper chambers and down again through the water in the upper chamber to the top of the intermediate chamber. When the water reservoir is charged, the water descends into the intermediate chamber, until its level rises above the top of the wick tube leading to the carbide chamber. Water descends to the carbide, and some of the gas generated passes to the burner, while the excess escapes to the upper part of the intermediate chamber, and when the pressure becomes sufficiently great it forces back the water in the intermediate chamber up the tube depending from the water reservoir, until the water level is below the top of the wick tube, and water ceases to flow to the carbide.

Dargue, W. H. Newcastle-on-Tyne 9023 Apr. 19, 1898

Producing Acetylene.

The carbide is placed in a porous receptacle which is then covered with a bell, in which a ring to sustain the porous vessel is fixed, thus creating a small gas chamber. The whole is

Grand, J. Lyons 9269 Apr. 21, 1898

immersed in a reservoir filled with water. The water, upon reaching the outer side of the porous vessel, creates a humid atmosphere within the vessel, and acetylene is generated. Accumulation of gas under pressure forces back the water from contact with the porous vessel.

Producing Acetylene.

Javal, A.
Neuilly
9319
Apr. 22, 1898

Carbide is fed into water, successive charges being introduced automatically, in proportion as the gas produced is consumed.

Acetylene Lamps.

Kitchen, J. G. A.
Manchester
9384
Apr. 23, 1898

Water passes from the upper water reservoir through an orifice leading to a passage fitted with a cock. Over the orifice is a pad of absorbent material, and upon the pad is a metal plate which can be compressed upon it by means of a screw actuated by a handle on top of lamp. The pad has a central hole through which passes the upper portion of an inverted perforated cup. The plate which compresses the pad is dished in the middle so as not to press upon the cup. Water percolates through the pad, and drops upon the carbide in the bottom of the lamp. Accumulation of gas under pressure retards the flow.

Gas Generator.

Williamson, A.
Greenock
9545
Apr. 26, 1898

A cylindrical chamber is divided into three compartments, the lowest being again divided into two to form two generators. Water descends from the middle compartment on to the carbide; the highest chamber is an overflow. Pressure of gas regulates the water supply.

Acetylene Lamps.

Melhuish, J. B.
Guthrie, M.
and
Hughes, J. H.
Birmingham
9674
Apr. 27, 1898

The cylinder containing carbide has a water jacket around it and a water well below it. The carbide cylinder may be surrounded by a circular wick turned over at upper edge so as to extend downwards within the cylinder, or the carbide may surround a circular wick stretched around a perforated tube. Above top of cylinder is a funnel into which water may be pumped by aid of a small cylindrical pump attached to side of generator, in order to start generation more rapidly than by capillary attraction. Fitting over wick surrounding carbide cylinder is an open-ended cylinder, which allows the carbide cylinder with its wick to be pushed down a short distance if a large surface of wick is to be exposed to water, or pulled upwards within the cylinder if capillary attraction is to be retarded.

Generating and Burning Acetylene.

Water reservoir on top, carbide chamber below. The flow of water to carbide depends upon pressure exerted by adjustable screw upon porous material through which the water must pass. The carbide chamber contains a drum, which can be rotated from outside by spring crank. The drum receives several closed carbide cartridges, which may be perforated when required by a pressure rod (with cutting edge and grooves) extending to outside of water chamber. One hole is made to admit water, and another for gas outlet. The burners may be provided with internal cleaning needles operated from outside, or the needles may be fitted outside the burners and brought into action by the compression of springs.

Strakosch, M. and Schmid, F. Vienna
9718
Apr. 27, 1898

Acetylene Generator.

The generator is attached to the side of a gasholder. The fall of the gas bell causes a projection attached to its cover to come in contact with a tumbler lever operating a pin and spindle, whereby water is made to flow from an overhead reservoir to the carbide within the generator. The rise of bell stops the flow. A non-return valve is fitted at top of pipe, which admits gas to bell. In another form the carbide chamber is above a tank of water, and the descent of gas bell causes carbide to be fed to water, while its ascent prevents the feed.

Haigh, B. London
10023
May 2, 1898

Portable Generators.

Water in upper, carbide in lower chamber. The valve which allows water to pass to carbide chamber is so attached to the gas outlet stopcock that the valve closes when the cock is closed. When, however, the outlet cock is open, the valve is regulated by the pressure of gas within the water reservoir; for the gas, leaving carbide chamber, passes to upper part of reservoir, where it exerts its pressure upon surface of water. As the gas pressure increases, the valve closes and decreases the rate of water flow, until, at a certain pressure, the flow entirely ceases.

Saxl, I. Vienna
10056
May 2, 1898

Producing Acetylene.

Water is sprayed over carbide, the generators being placed beneath a gasholder, with movable bell. The water supply is regulated by the movement of the bell.

Voro, F Selmeczbanya, Hungary
10141
May 3, 1898

Acetylene Generator.

The generators consist of carbide holders provided with bells, in which the delivery pipes enter. The water inlets are arranged at various heights, and water is passed into the carbide vessels successively, the pressure controlling the supply. A purifier is used.

Schulke, J. H. Berlin
10305
May 5, 1898

Acetylene Lamps.

Barltrop, W. P.
London
10684
May 10, 1898

The upper water chamber is detachably connected to the lower carbide chamber. The valve in the bottom of the water chamber is controlled by a rod passing up vertically through the chamber and terminating outside in a button. Vent-holes in the screw-cap allow air to enter and excess gas to escape. The water regulator consists of a metal tube, threaded inside, passing vertically upwards and having a number of small holes one above the other to allow drops of water to enter. Within this tube is the regulating rod which, when screwed down, closes the holes, and when drawn upwards opens them in succession.

Acetylene Lamp Generators.

Bilbie, J. and Drivet, H.
London
10985
May 13, 1898

The cylinder containing carbide is held centrally within a larger cylinder by springs soldered on opposite sides of it. The larger cylinder receives the water. The carbide cylinder is covered by a centrally perforated and removable lid having a gas eduction pipe leading upward from the central perforation. The pipe terminates in a curved end, with a nipple to receive one end of an indiarubber tube. The carbide cylinder is also furnished with a bottom situated some distance from the end of the cylinder; and inside the cylinder is arranged a curved perforated tube, two branches of which are soldered within the cylinder, one branch on each side. Through this tube a wick is passed in such a manner that the lower end passes under the bottom-plate within the cylinder, while the upper portion passes through the curved tubes, which are united by a coupling ring or sleeve. The whole wick forms an endless band, having its lower portion dipping into the water which rises in the carbide cylinder in the space beneath the bottom plate when water is poured into the outer cylinder. By capillarity the whole wick absorbs water, and communicates it through the perforations in the tube to the carbide.

Producing Acetylene.

Strode, W. W.
White, G. H.
London
11161
May 16, 1898

A water wheel is provided, connected with a carbide feeding device, consisting of a hollow rotating vessel, part of which is internally divided into a spiral passage. A holder described in a previous patent is used to collect the gas, the surplus water driving the water wheel. The rotating carbide vessel is in connection with a hopper projecting some little distance into it.

Acetylene Generator.

Kieffer, F. A.
Paris
11261
May 17, 1898

A gasholder bell carries inside it a carbide receptacle, the feed valve of which is worked by a float. Another carbide vessel above the interior one allows of fresh carbide being introduced.

Generating Acetylene.

An outer tank containing water has within it an inverted tank in upper end of which is fixed a hollow plugged tap to receive carbide. On lower end of inverted tank below water level, is a perforated tray upon which the carbide falls when the plug tap is turned. When tap is turned to discharge carbide, the plug at same time closes, so that gas cannot escape through it. If generation exceeds consumption, the gas pressure drives level of water below perforated tray. Before passing to point of consumption or storage holder the gas is led through a washer. Drain cock for removal of waste water is provided.

Shackleton, J. and Ross, A. **Antrim** 11367 May 18, 1898

Manufacture of Acetylene.

See Patent No. 14742 of 1897.—Two generators, each having a water inlet, gas exit, and drain cocks, are so connected together as to be simultaneously operated by a common handle, the water inlet cocks of the pair being also connected together in such a manner that the act of cleaning either of them will open the other.

Fowler, T. R. **Seacombe** 11377 May 19, 1898

Acetylene Cycle Lamps.

The carbide chamber is at base, and the water reservoir at back of lamp. In the carbide chamber is a perforated tube packed with absorbent material. In the pipe connecting water to carbide chamber is a ball check valve and a branch gas circulation pipe, whereby the flow of water is controlled by the difference in pressure between water column and gas. The water falls upon the absorbent material, from which it passes through the perforations to the carbide. A funnel-shaped deflector plate fits loosely into the perforated tube.

Wells, H. W. **Philadelphia** 11636 May 23, 1898

Acetylene Generator.

Within the bell of a gasholder is a partly perforated rotating barrel to contain granular carbide. The barrel is suitably journalled and situated above the water in the holder tank. The crown of the gas bell is fitted with a removable lid. A flexible chain is fastened to one end of rotatable barrel, from which it passes vertically downwards through a guide tube to a pulley, then up through a second tube to a catch on the gas bell. A separate chain also attached to the barrel terminates in a suspended weight, the tendency of which is to drag round the barrel until its mouth is on the underside and discharges carbide. When the gas bell rises it drags its chain with it, and pulls round the barrel until its mouth is in such a position that carbide ceases to fall from it. If preferred, the barrel may be

Ely, H. **West Bromwich** 11566 May 23, 1898

stationary and have a bottom orifice closed or opened by a rotating shutter actuated by the gas bell.

Acetylene Lamps.

Forbes, Sir C. S.
Strathdon
11716
May 24, 1898

In the lower part of the lamp is a cup-shaped receptacle containing carbide, and above this is a reservoir divided by a horizontal diaphragm into two compartments. In the diaphragm a central hole is bored, and into this is fitted a tube, which passes up to the top of the reservoir to a dome-shaped cover, which terminates outside the reservoir in a cock and burner. Another smaller tube passes vertically upward from the top of the carbide receptacle through the larger tube almost to its dome. This inner tube has a water inlet nozzle let into its side, and terminates at its lower end in a distributor. The upper compartment of the reservoir being charged with water, the water passes down a depending tube fitted in the diaphragm, and rises in the lower compartment and the larger tube until it reaches the inlet of the nozzle let into the smaller tube. Water passing through the nozzle drips upon the carbide. If gas production exceeds consumption, the gas pressure forces back the water level until it is below the inlet of the nozzle.

Portable Acetylene Lamps.

Bartlett, J.
Tottenham
11910
May 25, 1898

The lamp has an outer case for storing the gas, and an inner chamber containing a chamber for carbide, and two receptacles for containing water. The water passes through perforations to the carbide chamber, and the gas passes through perforations to the outer casing, which is fitted with an upper chamber containing wadding or similar material. The gas passes through this purifying material before reaching the burner. Water being introduced into the lower water receptacle, it comes in contact with some absorbent packing, through which it slowly permeates to the carbide.

Lantern for Acetylene Burners.

Falk, S.
London
12012
May 26, 1898

Two tubes are arranged one within the other. The inner tube serves to carry off the products of combustion, whilst fresh air is admitted in the space between the tubes. Around the lower ends of the tubes is a globe which encloses the burners, the outer tube being enlarged to embrace the upturned mouth of the globe. Around the lower end of the outer tube are a series of apertures for admission of air, a deflector to stop injurious air currents being arranged adjacent to them.

Generating Acetylene.

Carbide is dropped into water, the arrangement being actuated by a motor operated by the rise and fall of the gasholder bell, the speed of the motor being regulated, but its motion never stopped. A purifier is used.

Dreske, P.
Berlin
11964
May 26, 1898

Acetylene Generator.

The generator has an open charging space, and a closed bell communicating with a gasholder. A long-handled receptacle adapted to hold the carbide is provided, so that a charge of carbide may be readily introduced under the bell, and the residue be conveniently withdrawn. The top of the receptacle is so perforated that when the acetylene is being generated at a sufficient rate the admission of water is prevented by the issuing gas.

British Pure Acetylene Gas Syndicate, Ltd. & T. Keene
Liverpool
11970
May 26, 1898

Acetylene Generator.

Improvements in Patent No. 20903 of 1896. A supplementary generator charged with carbide is attached to the side of the gasholder, so that manufacture of gas may be continuous.

Sardi, V.
Turin
12182
May 28, 1898

Acetylene Generator.

The generator is connected to the gasholder bell, underneath which rails are arranged, which start from the exterior of the generator, and lead down at a sharp angle into the water in the generator. On these rails cartridges of carbide travel. A mechanical device is provided, which causes the gasholder bell, at a certain position, to discharge a cartridge on to the rails, down which it slides into the water. The cartridges consist of perforated casings, filled with carbide.

Gesellschaft fur Heiz & Beleuchtungwesen
Heilbronn
12250
May 31, 1898

Acetylene Generator.

A water supply pipe passes from lower part of a gasholder water tank to bottom of generator containing carbide. Around upper portion of the supply pipe which is within the gas bell, and which may terminate in a T with slightly curved ends, is a float having a central metal pipe passing through and above it. This pipe is of larger internal diameter than the exterior of water supply pipe, so that float may slide freely upon same. On top of float and surrounding the float pipe is a cup partially filled with mercury to form a mercury seal for the curved T ends of the water supply pipe. One or more brackets are fixed to top of float, so that when gas bell descends, its dome will come in contact with the brackets and cause the float to descend until the T ends are withdrawn from the mercury, and water can pass to the generator. When bell rises, the float also rises, and the mercury again seals supply pipe. To enable generation to

Scarth, J. E.
Pudsey
12401
June 2, 1898

proceed continuously, two or more generators may be provided one to be cleaned while the other is in operation.

Producing Acetylene.

Ernst, O.
Philips, A.
Germany
12510
June 3, 1898

A generator and gas collector are fitted in a water tank and surrounded by a bell. Means are provided for preventing escape of gas during charging. The pressure of gas controls the water supply.

Acetylene Generators.

Levetus, E. L.
Birmingham
12469
June 3, 1898

Two compartments: water at top, carbide below. In the water chamber is a syphon tube, having its longer limb extending through division plate between the chambers and down into the carbide chamber. Its lower end is contracted, while the mouth of the short limb, which opens near the bottom of the water chamber, may be provided with a tap capable of being operated from outside the casing. A safety pipe may extend from top of gas chamber up through top of water chamber, where it terminates in a valve. The water fed through syphon drops on to carbide, and the gas passes to burner. The end of syphon tube in carbide chamber may have several branches to facilitate distribution of water over carbide.

Acetylene Generators.

Società Italiana del carburo di calcio acetilene ed altr gas
Rome
12491
June 3, 1898

Carbide is fed automatically or by hand into a water reservoir from a carbide chamber by a feeding device comprising a rotating disc and discharging blades. The rotation is effected by clockwork mechanism. The carbide discharge valve may be automatically closed by the ascent of the gasholder bell, and opened by its descent. The bottom of the water chamber is funnel-shaped and provided with a discharge pipe and cock. Outside the water chamber a vertical pipe extends upward from the horizontal discharge pipe, and is provided with a rod carrying a kind of piston valve. By introducing this rod and piston valve into the vertical pipe and working it like the plunger of a pump, the lime sludge may be removed without stopping the working of the generator. A bell safety valve and means for supplying fresh water to the reservoir are provided.

Generating Acetylene.

Jackson, F. A.
Tunbridge
13029
June 10, 1898

The descent of the gasholder automatically at a certain point causes a charge of carbide to be dropped into a large excess of water. The charge passes into the generator through a metal shoot. Above the generator is a gasholder, connected with it by a pipe. The top of the shoot is provided with a revolving disc, the working of which depends on the movement of the

gas bell. Charges of carbide are mounted on this disc in containers, and at a certain point in the descent of the gas bell the contents of each are discharged down the shoot. The water in the shoot is preferably covered with a layer of oil.

Acetylene Generator.

One or more water-jacketed generating chambers are supplied with water from superposed tanks. The carbide is contained in a drawer which slides into the generating chamber. Within the water tank is a displacement gas bell held to its seat by a metal band. From a hole in the top of the generator a pipe extends vertically upwards to the top of the gas bell. At a certain distance up in the bell this pipe is provided with a dripping nozzle, inserted in a downward oblique direction through a hole drilled in the pipe. Water drips upon the carbide; and if the gas production exceeds the consumption, the gas collects under pressure in the bell, and drives out the water, so that water ceases to be supplied to the nozzle.

Forbes, Sir C. S.
Strathdon
13070
June 11, 1898

Generating Acetylene.

A mechanical closure and water seal are provided for the carbide feed tube in those generators in which carbide is fed into water.

Lipcke, P.
Charlettenberg
13387
June 15, 1898

Portable Lamp.

The carbide holder is supported by a perforated cylinder, and has a base with a circular aperture, the edges of which bear blades of different length, directed radially towards the centre and continuing in the curvature of the ovoid holder. The interstices between the blades are capable of simultaneously retaining or supporting the fragments of carbide in the receiver, and of allowing the lime paste to flow through. The cover of the holder being immovably fastened by a bayonet catch, the expansive force of the decomposing carbide accelerates the passage of the lime paste. The water for decomposing the carbide contains 120 to 130 grams of saccharose. The cylinder on which the carbide holder is supported contains at base an annular gutter, in which the lower end of a perforated cylinder is secured. Between the cylinders a floating bell moves concentrically, and is provided with flexible gas outlet tube. The gas traverses a series of pieces of metal gauze between bell and burner. Openings in the perforated cylinder receive sounding blades, which, when bell ascends or descends, are acted upon by pins and create a noise to act as annunciator. The flow of water to carbide is automatically controlled by gas pressure within bell.

La Société Chaussard et Cie and Vignes, C. E.
Seine
13573
June 17, 1898
Cl. Nov. 22, 1897

Generating Acetylene.

Forbes, Sir C. S.
Strathdon
13636
June 18, 1898

See previous patents. 11716 and 13070 of 1898. The present claims include the combination of an acetylene generator having a superposed watertank with a combined gas and dripping tube, so constructed that the gas pressure vessel is supported by and turns thereon, thereby opening or closing the nozzle through which water is admitted to the carbide.

Acetylene Lamps.

Josephson, G.
Berlin
13771
June 21, 1898

A standard lamp with a generator arranged in the foot. The generator consists of a cylindrical vessel of water, in which is immersed a second vessel resembling a diving-bell, and closed at bottom by a cover having a fine perforation. The upper part of the bell carries the gas eduction tube leading to the burner. Inside the bell is a plate or table which carries the carbide.

Acetylene Generators.

Payan, O.
France
13830
June 21, 1898

The generator is a water container having funnel-shaped base with drain cock. A vertical carbide shoot passes through top of reservoir to some distance above it, and terminates at top in a funnel. Above and at one side of this funnel is a horizontal plate cut away at the part which would project immediately over funnel. Over this plate a series of carbide receptacles move, each receptacle containing sufficient carbide to generate the gas required to fill the bell of gasholder connected to generator. Each receptacle has a cover, and a hinged bottom resting upon the plate. When the bell sinks to a certain position, the plate is caused to rotate by automatic operation of a mechanical contrivance, so that a carbide receptacle is brought over funnel, and the fall of hinged bottom allows carbide to fall down shoot into generator. The bottom end of shoot is covered by a plate, but this is automatically moved aside when carbide is discharged. The carbide, which is preferably impregnated with oil before use, falls upon a double cone in generator, which distributes it over the bottom of the generator.

Acetylene Lamps.

Forbes, Sir C. S.
Strathdon
13968
June 23, 1898

The carbide cup is in lower part, and the water reservoir in upper part of lamp. Threaded into the centre of the cover of the water reservoir is a cap having ports which admit gas to burner, a spindle which extends vertically downward and supports the valve which admits water to the carbide, and a bell, which revolves with the cap, and contains a circulating tube. When the cap is turned, water is admitted through the valve to the carbide. When production exceeds consumption, the

pressure of gas in the bell drives back the water until its level is below the valve.

Acetylene Generators.

The carbide vessel is formed of porous material, the pressure of gas regulating the water supply.

Billwiller, J. Rosenthal, K. Berlin 14050 June 24, 1898

Acetylene Generator.

Carbide falls into water from receptacles placed in the bell of a gasholder as the bell sinks. The carbide vessels are moved by turning a spindle at the side of the generator.

Rosenthal, K. E. Berlin 14049 June 24, 1898

Producing Acetylene.

Two independent generators are suspended externally from the bell of a gasholder and connected with it. The generators contain carbide in boxes in layers. The water comes in contact with the carbide when the bell descends, being led to the generators by flexible pipes.

Sez, H. St. Denis 14197 June 27, 1898

Acetylene Lamp.

A number of tubes are attached vertically to the under side of a water reservoir. The lower ends of the tubes are screw-threaded, and are provided with screw caps. To these caps are affixed tubes, which fit loosely into the vertical tubes when the caps are screwed on, and which rise to about two-thirds of height of outer tubes. The internal tubes have small perforations near base. The upper space within each outer tube is connected by tubing to the base of the succeeding tube. Water flows into the first tube, and then overflows into the other tubes in succession. The carbide is employed in the form of cartridges. The gas eduction tube passes from the top of the last of the tubes through the water reservoir to the burner.

Lewis, W. W. Davis, S. J. and Osmond, F. J. Smethwick 14149 June 27, 1898

Acetylene Generators.

See patent 29554 of 1896. Improvements in the method of bringing the chambers into action, also in the construction of the water valves and pipes.

British Acetylene Gas Co. Kirkaldy 14432 June 30, 1898

Cycle Lamps.

The carbide chamber is a cylinder perforated at bottom with very fine holes. A thick disc of felt inside the cylinder covers the holes, and the carbide is placed upon the felt. The cover of the cylinder is connected by a rubber pipe to the metal pipe leading to burner. The carbide chamber is introduced into a cylindrical reservoir containing water, in which it floats. Water penetrating the felt reaches the carbide. Excessive

Schröder, H. F. A. and Nehemias, M. J. Hamburg 14517 July 1, 1898

generation causes floating cylinder to rise, and also prevents water penetrating felt. A safety valve is provided.

Acetylene Generator.

Davoren, M
Belton, J. P.
and
Davoren, J.
Carlow
14567
July 1, 1898

From top of a gasholder bell depends a cylindrical vessel closed at bottom, but open at upper end, and furnished internally with a wire basket charged with carbide. The bottom of cylindrical vessel may communicate with inside of bell by a cock manipulated by a handle connected to a spindle which passes up through top of bell. When the bell is empty of gas, water is admitted to carbide by opening this cock. The gas passes through a pipe and cock in upper part of cylindrical vessel to a purifier and condenser. The purifier contains oxide of iron. A safety pipe is provided.

Producing Acetylene.

Fournicr, M.
Dresden
14616
July 2, 1898

The carbide is placed in receptacles within a case fitted above a slanting shaft communicating with a generator charged with water. The carbide receptacles are liberated and allowed to slide into the generator by the release of the covering sides of the case. The sliding arrangement is actuated by the bell of a gasholder, the sinking of the bell to a certain position successively allowing one carbide receptacle with its contents to slide into the water.

Generating Acetylene.

La Compagnie Continentale
Brussels
14713
July 4, 1898

The generator, half-filled with water, has a side feed tube, down which the carbide is fed from baskets attached to a vertical spindle. The charge is automatically tipped into the water by a lever actuated by the gasholder bell.

Generating Acetylene.

Gastaldi, F.
Turin
14729
July 4, 1898

Two similar generators are attached to a gasholder, and provided with pipes and with cocks, which are worked partly by hand and partly automatically. The generator is a cylinder having within it another cylinder perforated with small holes in its upper part, and carrying near its centre a horizontal grating, consisting of sharp edged bars with points projecting upwards. On this grating is placed the carbide in cakes or large pieces. The upper part of the outer cylinder is surrounded with a water-jacket communicating with the holder tank, and the bottom is provided with a hinged cover held by a suitable catch. The gasholder is comparatively small, as it is not intended to store gas, but merely to regulate its production and pressure. The gas inlet to the bell is through a helically twisted pipe, having its outlet above the level of the water in the holder tank. When water is allowed to rise to the carbide,

the gas passes through a washer and the twisted pipe to the holder bell. When the bell rises it closes a cock which communicates with both generators, and thereby causes the gas pressure in the generator to increase until it drives back the water from contact with the carbide. When the bell falls and reopens the cock it relieves the gas pressure, and allows the water to again flow from the gasholder tank towards the carbide.

Generating Apparatus.

Henriquez, E.
Brussels
15020
July 8, 1898

An annular water tank with central well is divided into two compartments, the lower being gastight and the upper open. A basket containing carbide is placed in the well connected with the water in the lower chamber. Pressure regulates the supply of water.

Acetylene Generator.

Marrs, W.
London
15175
July 11, 1898

Inside a water reservoir, closed at top by a removable gas-tight cover, is a bell-shaped generator, also having a gas-tight removable top. The carbide is contained in a movable basket within the generator. The bell is perforated around its upper part to allow water from the outer reservoir to enter when the bell sinks low enough. The burner cocks being opened, the air rushes out of the bell, which then sinks in the water until the perforations are below the water level in the reservoir. Gas is then generated and the bell rises, and water cannot again enter until the consumption of gas causes the bell to again sink. The gas escapes downward through a pipe to a storage chamber in the bottom of the water tank. It then passes to a cylindrical purifier, having beneath it a chamber and drain cock for withdrawal of condensed liquid. From the purifier the gas passes to the burner. A safety valve may be provided.

Acetylene Lamp.

Delmouly, E.
Paris
15179
July 11, 1898
Cl. Mar. 29, 1898

The lower part of the lamp contains carbide, and is connected to an upper reservoir containing water. From the centre of the bottom of the reservoir a long tube passes down to the bottom of the carbide chamber. This tube is open at both ends, and is packed with felt or similar absorbent material, or the tube itself may be a capillary tube. Another tube terminating in a cone, and furnished with side apertures, fits into the first tube and extends upward through the water chamber, at the top of which it is closed by a stopper. The tube in the carbide chamber is sheathed with another tube, closed at its lower end and perforated half way up its length. The perforated tube is covered with porous material. The water descends through the wick, and eventually reaches the porous material which is in

contact with the carbide. Increase of gas pressure prevents water flowing through the perforated tube.

Acetylene Generator.

Bohne, M.
Berlin
15423
July 13, 1898

The dome of a gasholder bell is provided with a carbide receptacle, beneath which is a balance, with regulating rod projecting downwards. This rod, when the gasholder is nearly empty, strikes against the bottom of the holder tank, opening the carbide hopper, and allowing carbide to fall into the water. As the bell rises the balance closes the carbide hopper. The gas generated passes through the carbide in the hopper, in order to dry it, then through a delivery pipe into the gas bell, where it is prevented from coming in contact with the water by a layer of oil.

Acetylene Lamp.

Schmitt, L.
Mannheim,
Germany
15688
July 18, 1898

Water reservoir at top, and carbide chamber at base of lamp. A comparatively long pipe extends from the reservoir to the carbide chamber ; and in order to prevent irregularity of water flow when lamp is shaken, the tube may either be bent into several convolutions, or the tube may be filled with porous wick. To keep the water outlet of the distributing tube clean, a needle passes vertically upward through the water valve to the outside top of the water reservoir, where it terminates in a button. The needle may be moved up and down by this button. Increase of gas pressure in the generator prevents flow of water. Insulating packing is provided between the lantern and the generator to prevent heating of the latter.

Acetylene Generator.

Dant, H.
Nuremberg
16090
July 23, 1898

A holder containing carbide vessels, and having a gas-tight lid and perforated at the bottom, is placed in a water tank. The carbide vessels are arranged at different heights, the pressure of gas controlling the water supply.

Acetylene Lamps.

Moore, W. N.
and
Karr, J.
16317
July 26, 1898

The water reservoir in the upper portion of the lamp has a controllable discharge opening in its base. A carbide holder is removably connected with the lower portion of the lamp. A wire gauze tube filled with an absorbent fabric extends from the base of the carbide holder to the base of the water chamber. The carbide holder is of less diameter than the lamp body, so as to leave an annular space to constitute a gas chamber. The bottom of the water reservoir is in the form of an inverted cone, having the discharge opening at its apex, and controlled by a needle valve. Water passes through this valve to the absorbent fabric, and from thence passes to the carbide.

Acetylene Generator.

The carbide is placed in a hopper on top of the gasholder bell, the mouth of the hopper being closed by a weighted cone. As the gas bell descends, the weighted cone comes in contact with an upright rod fixed centrally to the bottom of the holder tank, causing carbide to fall into water. The rising of the bell closes the mouth of the carbide hopper. The bell works in a separate annular chamber surrounding the tank holding the water for the carbide.

Williams, R. Edgbaston & Clarke, J. H. London
16479
July 28, 1898

Generating Acetylene.

The carbide holders are so arranged in the generator that they have a gradual rise in the form of a spiral. Division walls separate each holder from the other, save that the bottom of one holder covers the top of the holder beneath. Water is supplied from an overhead cistern, which has two compartments which are in communication. Each compartment has a valve actuated by a rod connected to a swing lever above the cistern. Water passes from one compartment into the other, and from thence into the generator. The water valves are automatically operated by the bell of the gasholder, the ascent of which prevents discharge of water, while the descent, to a certain point, causes the discharge of the contents of the lower compartment of the cistern.

Berger, H. R. Berlin
16457
July 28, 1898

Acetylene Generator.

Water passes from gasholder tank to a generator containing perforated basket charged with carbide. The gas passes through pipe and valve to cooling and purifying chamber, and from thence to gas bell. The purifier contains hydrochloric or other acid to remove ammonia, and a tray containing caustic potash or soda and a top layer of calcium chloride. When the bell is nearly filled it automatically closes the cock which admits water from tank to carbide. Gas subsequently produced in generator tends to force back the level of water from perforations in carbide basket. A safety valve is provided for escape of gas which may accumulate under abnormal pressure.

Legge, J. H. C. Dublin
16487
July 29, 1898

Generating Acetylene.

Two concentric cylinders are mounted upon a water tank, having a condensing chamber at one side. The space between the two cylinders contains water, which forms a seal for a bell. Within the bell is a carbide holder, conical at its lower end, and charged with powdered carbide. The lower end of the

Testelin, C. and Roseaux, C. Paris
16613
July 30, 1898

carbide holder contains a spring-controlled spherical valve, and opens into a second smaller carbide holder, also provided at its lower end with a spring-controlled spherical valve. When gas bell sinks it bears upon a rod, and first opens the valve of the lower carbide holder. If the lower holder be empty, the bell continues to sink, and opens the upper valve, which allows carbide to fall from upper to lower holder. When bell rises the valves close. The gas is subsequently led through a purifier outside generating apparatus, from which it passes to burner.

Acetylene Lamps.

Hedgeland F. W. Chicago 16723 Aug. 2, 1898

The carbide receptacle is covered by a fixed bell, in the top of which is the gas eduction tube leading to the burner. The carbide chamber is in connection with a water tank, which may surround the bell or be separate from it. In the lower part of the carbide receptacle is a short horizontal passage or chamber which receives water at its bottom, and gas under pressure through an opening in its top. When generation of gas becomes excessive, the pressure of gas forces the water away from contact with the carbide, and when the pressure diminishes the water flows back to the carbide.

Generating Acetylene.

Evans, E. Denbigh 16733 Aug. 2, 1898

An auxiliary water chamber is provided to feed main water chamber on the "bird-fountain" principle, in order to reduce the necessary size of the water chamber in base of lamp. In lower part of lamp is a tubular gas container, inside which a number of tubes, each containing a specially devised carbide holder having hinged and perforated doors, are placed. The holes for admitting water to the tubes are at different levels. Around the gas container is the main water chamber. Water enters the gas container through a valve at bottom, and passes into the carbide tubes in succession.

Acetylene Gas Producer.

Varon, J. Bordeaux 16884 Aug. 4, 1898

The carbide distributor is placed in a horizontal casing, and is composed of two or more bucket wheels mounted on a common shaft. A rectangular box, extending downwards, is attached to the lower part of the casing, and has a carbide dispersing cone at the lower end. Beneath the distributor is the water container. A hand-wheel on the shaft rotates the distributor for re-filling, the number of buckets used being shown by an index, and an electric alarm is provided to give warning when the last bucket has been emptied.

Producing Acetylene.

Water is automatically sprayed upon carbide. Horizontal cylindrical chambers are situated in lower part of a gasholder tank, and have their mouthpieces extending through wall of tank. Into these chambers perforated vessels containing carbide are introduced. From an aperture inside of gasholder tank a small water supply pipe leads to a sprinkler fixed within upper part of each cylindrical chamber, the handle of stopcock on pipe being formed by a lever, which is so arranged that the cock is closed when the gas bell is raised, but is opened, by contact with a tappet fixed to bell, by the descent of bell to certain position. Separate stopcocks, actuated by tappets arranged at different levels, are provided for the different generating chambers.

Higgins, W. and Sandilands, H. London
15977
Aug. 4, 1899

Acetylene Generators.

12 claims, 37 figures. A charge of carbide is automatically discharged into a generator containing water each time the bell of a gasholder descends to certain point. The carbide may be used in the form of cartridges, or may be spherical charges arranged within a vertical column. An automatic step-by-step rotary motion is imparted to the bell by a movable oblique finger attached to bell being engaged during descent between a series of studs. The finger moves from oblique to vertical position when bell rises. Or the step-by-step rotation may instead be imparted to the cartridge-releasing device. The carbide distributor partially surrounds the upper part of the gasholder tank, and comprises a series of chambers wherein are pivoted the carriers which discharge carbide when the finger on the bell comes in contact with one extremity of a carbide chamber. Various modifications in arrangement and form of apparatus are described.

Montais, M. L. J. R. L. de France
16903
Aug. 4, 1898

Producing Acetylene.

To prevent the production of a constant strong smell from the apparatus by means of a device which allows the water to attack the carbide only when the apparatus is hermetically closed. The washing apparatus effects a thorough removal of the waste carbide.

Gehlert, F. Basle
17079
Aug. 8, 1898

Acetylene Lamps.

18 claims. Water reservoir above, carbide chamber at base. Between the two chambers is a gas chamber, through which gas from carbide chamber passes on its way to burner. A central gas tube passes vertically through water chamber and carries at top a tubular support fitted with burner, and in its lower end a channelled plug. An inclined tube containing a

Schumacher, J. Chicago
17088
Aug. 8, 1898
Cl. June 20. 1898

plug valve also passes from bottom of reservoir to upper part of casing, where the valve terminates outside the casing in a handle. Water passes through channels in plug valve to a compressible felt valve, and from thence down a depending stem covered with porous material, which is surrounded by the carbide. Within the burner is a cleaning needle, the point of which penetrates the burner orifice when the burner is pressed down upon its spring support.

Acetylene Lamps.

Schieroni, F. E. London 17269 Aug. 10, 1898

The inner vessel containing carbide has a dome cover with overlapping flange to form a cover to outer water vessel, in which the carbide vessel is contained. The lower end of carbide container is closed by a cork. A wick tube passes from upper part of container down through cork and dips in water in outer vessel. The wick can be compressed by side screw having head outside of lamp. The upper end of wick falls slightly over top of wick tube to convey moisture, but not liquid water, to carbide. The gas escapes through dome to valve or cock, and from thence to burner.

Acetylene Lamps.

Schwarz, I. Berlin 17350 Aug. 11, 1898

Carbide vessel at base of lamp, water reservoir above. Carbide chamber instead of being screwed is tightly attached to body of lamp by aid of rubber disc. A special water inlet valve, provided with an indicating device having a spring pointer attached to an adjusting disc, is also claimed.

Acetylene Lamps.

Spence, H. K. and The British Acetylene Gas Generator Co. Kirkcaldy 17327 Aug. 11, 1898

Water is contained in the lower portion of the outer casing, which has within it a gas-containing chamber with a tubular aperture at its base, through which a wick passes to the water. Inside the gas chamber is a carbide holder having a perforated bottom, and attached to a spindle which passes gas-tight through the top of the outer casing. By means of this spindle the carbide holder can be lowered until its perforated base rests upon the wet wick when gas is required, or raised from it when gas is not required. The gas escapes from apertures in top of carbide holder by a pipe in the gas container to the burner.

Acetylene Cycle Lamps.

Jeapes, W. C. London 17405 Aug. 12, 1898

The tubular handle bar and its stem serve as the water receptacle, and within it is fitted a removable carbide holder provided at bottom with a perforated plug. A vent is provided at suitable point in handle bars to allow air to enter as level of water falls. A safety valve may also be provided. The car-

bide holder is provided at top with a projection, which engages with a bayonet joint slot in top of cycle stem. The top of the carbide holder is screw threaded, and on the thread is mounted the cup portion of a ball joint, a tap being arranged in this portion to enable gas passing to burner to be controlled. The ball carrying the burner and lamp casing is retained in the cup by a ring.

Acetylene Generator.

Manger, T. **Bamberg** 17449 Aug. 13, 1898

Two generators working alternately are supplied with water according to the movement of the gas bell.

Generating Acetylene.

Emmerson, G. W. **Newcastle-on-Tyne** 17504 Aug. 13, 1898

The water tank is situated above the carbide chamber, and a gas bell rises and falls in the tank. The carbide chamber is provided with doors for introducing the trays charged with carbide. The space below the trays is filled with water. A weighted valve is fitted at top of the gas eduction pipe, which passes from the carbide chamber to just above water level in tank. When the bell is nearly empty some part or projection of it presses on a lever, opens the valve, and permits gas to pass. As the bell rises the valve closes. Increase of gas pressure in the carbide chamber forces back the water from carbide into the tank. When gas in bell is consumed, the bell again descends, and by opening the weighted valve simultaneously allows gas to pass from carbide chamber to bell, and water from tank to carbide.

Acetylene Lamps.

Buffington, F. S. **Minneapolis, U.S.A.** 17587 Aug. 15, 1898

A lamp for miners. The generator is attached to lower part of lamp. The acetylene is conducted into and burned in a chamber, to which the outside atmosphere can only find access by traversing wire gauze. The lamp is lighted by means of an electric spark or a wire heated to incandescence by an electric current. The walls of the combustion chamber are preferably constructed of glass, with longitudinal passages to convey air to the flame.

Acetylene Generators.

Gillet, C. R. and E. W. **Chicago** 17612 Aug. 16, 1898

The generator is a cast metal box having a tray charged with carbide carried upon horizontal internal ledges. The bottom of the tray is perforated or of wire network. A deep pan containing a layer of water rests upon the bottom of the generator, and serves as a receptacle for the spent carbide and surplus water. By means of a crank arm outside the generator the tray can be shaken, and the spent carbide dislodged from the unspent material. A clip suspended beneath the tray also

carries a lump of carbide, which is precipitated into the pan beneath when the crank arm is rotated. Above the generator is a reservoir from which water descends through a valve, a stopcock, and absorbent wick to a serrated absorbent curtain suspended in the generator over the carbide tray. When the valve controlling the outlet of gas to the burners is closed, the gas generated by the fall of the lump of carbide into the pan passes to the top of the water reservoir, and tends to force the water through the absorbent material to the carbide in the tray. The main gas valve is now opened, and gas passes to the burners. The accumulation of gas pressure within the generator prevents the continued descent of water.

Acetylene Generator.

Drivet, H. & Bilbie, J. London 17734 Aug. 17, 1898

The generator consists of a water tank, provided with a water discharge pipe and gas supply pipe, and carrying a central gasholder and two carbide distributors. Each carbide receptacle is provided with a scraper, formed of a hollow stem fitted with blades. The carbide receptacles are truncated, the inner periphery of the small base of each being provided with teeth gearing, with a conical wheel mounted on the lower end of a vertical shaft. When the gasholder descends, the vertical shaft rotates, distributing the carbide into the water in the tank below.

Cycle Lamps.

Buffington, A. L. Minnesota, U.S.A. 17920 Aug. 19, 1898 Cl. Jan. 20, 1898

A spherical lamp containing an annular water chamber, which in its upper part is normally closed by a cap or plug perforated with very small vents. The carbide holder consists of two parts, made of alternate layers of perforated metal and absorbent material. The metal portions are placed in direct contact with the carbide, which is coarsely pulverised. The carbide chamber is in the centre of the lamp, and is surrounded by the water chamber. The generating action is started by moving a valve in the bottom of the lamp, which opens the water feed passage. The water flows to the generating chamber under a pressure equal to the height of the column of water in the lamp. The water comes in contact with the absorbent material, which conducts it around the carbide. Sixteen claims are made.

Acetylene Generators.

Thorp, T. Whitefield 17840 Aug. 19, 1898

Generator consists of cylindrical chamber built in horizontal position in lower part of gasholder tank, and having its open exterior end closable by gas-tight cover. The carbide box which slides into generator is divided by hollow partitions, up which water rises until it overflows to carbide. The box is so

formed that when in position a space remains below and around the box to form water jacket. The top of generator is provided with vertical gas pipe leading through a water seal into gas bell. The inlet for water from gasholder tank is in centre of tank-bottom, and underneath it is a gutter arranged to convey water beyond the end or sides of carbide box, so that water will not drop upon carbide, but rise from bottom up hollow partitions to it. Water inlet pipe is controlled by three-way cock. At a short distance above the cock, in the pipe surmounting it, is valve seating and inverted valve, the stem of which at upper end is connected to disc fitting loosely into tube and provided with arms extending through slots in the tube into the tank, and fitted with floats. Above this disc is another disc connected by adjustable rod to top of gas bell. When bell sinks, the valve opens; when bell rises, the valve closes. The three-way cock has spindle terminating outside tank, so that water can be withheld from generator altogether, or be made to pass through lateral passage from position uncontrolled by valve to generator, or through vertical passage in which water feed is controlled by the regulating valve.

Acetylene Generators.

Ward, L.
Cape Town
17892
Aug. 19, 1898

A tank is divided by horizontal partition, having a central circular opening, to the edge of which is attached the upper end of a cylindrical tube, which extends down nearly to bottom of lower tank. Within this tube is the carbide chamber, consisting of a cylindrical vessel passing through the bottom of the lower tank. The gas outlet pipe extends upward, and is coiled within the upper tank for cooling and condensing purposes. The bottom of the carbide cylinder is closed by removable cover. The carbide cage consists of two hollow cylinders perforated, or formed of wire gauze, cut away through a part of the periphery, and placed one within the other, so that they may have the same geometric axis, and the inner be capable of rotation within the outer. The inner part of cage may be divided into any number of compartments. The cage is supported upon a sliding rod. Water poured into upper tank flows down between carbide cylinder and outer cylinder until the lower tank is full, and rises in the upper tank for a few inches above the horizontal division plate. When cock is opened water passes by pipe from upper part of lower tank, and rises within the carbide cylinder, where it comes in contact with carbide in lowest compartment of cage. When generation of gas exceeds consumption, the gas accumulates in top of lower tank, and forces back water until its level is below inlet of supply pipe.

Acetylene Apparatus.

Gustafsson, K. G. Stockholm 18063 Aug. 22, 1898

Carbide is fed into water covered with a layer of oil through a side shoot. The carbide falls into a wide tube containing water without the layer of oil.

Acetylene Lamps.

Miller, C. A. and Miller, F. J. Birmingham 17997 Aug. 22, 1898

The carbide holder, which forms base of lamp, may be internally fitted with a spring clip for a carbide cartridge consisting of carbide enveloped by a thin case pierced, prior to use, with a series of holes. The carbide chamber is separated from gas chamber and filter chamber by a diaphragm pierced with a small hole. The upper part of lamp constitutes water reservoir, and communicates by a passage controlled by a valve, capable of being externally operated, with the carbide chamber. The external head of the valve spindle is provided with an index with limiting stops, to be employed in conjunction with a fixed pointer secured to body of lamp. Within carbide chamber, instead of cartridge there may be a removable bottom plate carrying an upward vertical perforated tube, through which water passes to carbide arranged around tube. Gas passes through small hole in diaphragm to gas chamber, and through filtering material to burner.

Acetylene Generator.

Kremer, J. Gilly, Belgium 18133 Aug. 23, 1898

See Patent No. 26776 of 1897. The present improvements consist in the addition of a small vessel beneath the generator, communicating therewith by a cock, and which serves as a receptacle for the carbide residue. The regulating rod is extended to the top of the gasholder by means of a rod of smaller diameter, protected by a sheath. By this means the jamming of the regulating rod, as it passes through the carbide, is avoided.

Acetylene Generator.

Engasser, Emil Alsace 18220 Aug. 24, 1898

One or more vertical cylindrical generators, having semicircular carbide trays arranged at different heights on a common central rod, are provided. The generator is connected to a gasholder, the bell of which controls the supply of water to the carbide by its rise and fall. The gas generated passes through a leaden purifier and a vertical pipe, having its upper end bent and dipping into the water in the tank, to the bell. On leaving the bell the gas passes through a cooling worm contained in the gasholder tank. The holder bell will hold rather more gas than is generated by the carbide contained in any one tray. When two generators are provided, a device is supplied to cause the water from the one generator to automatically overflow into the second generator. The water for the generator is supplied from an overhead tank.

Acetylene Lamps.

The valve between upper water chamber and lower carbide chamber is connected to a vertical spindle, actuated by a rack and pinion wheel, and terminating in a knob outside casing. The knob is provided with a stop piece, and a stop piece is provided on side of casing, so that the limit of rotation of spindle is the lift of the valve. Within the tube which conducts gas from carbide chamber to burner is a wire or pricker, suitably connected to a screw-threaded piece, and so arranged that when the screwed piece is rotated in one direction the pricker passes up through orifice of burner, and when rotated in opposite direction is withdrawn below the burner.

Stearnes, H. and Wilson, S. Manchester
18197
Aug. 24, 1898

Acetylene Generator.

For regulating the water supply to the carbide. At a certain pressure in the generator the water sinks within the sight-feed vessel below the exit feed pipe, and flows back into the water container. On the pressure being relieved, water again rises in the feed vessel, and flows to the carbide. Fresh charges of carbide can be supplied whilst the apparatus is working.

Walker, W Aberdeen
18178
Aug. 24, 1898

Acetylene Generators.

Two or more generators or sets of generators are connected to gasholder, so that while one is being cleaned the other may be in operation. Each generator has a carbide receptacle into which water enters through side perforations. The gas collects in bell covering carbide receptacle, the bell having double walls forming a water jacket, and being itself immersed in hydraulic seal. From top of bell gas descends to an inclined pipe, from which it passes to main gasholder bell. All generators are contained in the compartments of one main vessel separated by partitions, over which water supplied to one compartment of a set flows to other compartments of the same set. In each compartment water enters the bell through perforation near its base. When the bell of the main gasholder rises above a certain point it raises a flexible tube, forming outlet from water supply cistern, and thus cuts off supply to generators. Also when the bell reaches a certain height it opens a safety cock, and allows gas to escape.

Matthyssens, G. Antwerp
18436
Aug. 27, 1898

Production of Acetylene.

Fifty or more carbide compartments successively discharge their contents into a tank of water situated beneath the distributing drum. The discharge is automatically effected by the bell of a gasholder by means of a ratchet wheel keyed upon the shaft of the distributing drum. A trough containing water surrounds the generator, and serves as a gas washer. In the

Quattannes-Moens, R. and Dilger, C. Belgium
18591
Aug. 30, 1898

generator is a sieve, upon which the carbide falls after leaving the distributing funnel. A pipe leads the gas from the gasholder to the point of consumption, and another pipe branching from this pipe extends down to the bottom of a closed vessel, which constitutes a bubbling-up device or leak indicator. The gas after leaving the holder passes through a purifier containing a layer of sulphate of iron, a plug of wadding, and a layer of calcium chloride.

Generating Acetylene.

Wilson, F. C.
Chicago
18741
Sep. 1, 1898

The lower part of a gasholder tank is provided with partitions to form a water supply chamber and a generating chamber. One end of the generator projects through wall of water tank, where it is provided with movable cover. The carbide is contained in a movable drawer, which is provided at some distance from its bottom with one or more gratings to support carbide, while residue drops through to bottom of drawer. The gas passes to bell, which in its ascent lifts weights arranged at different levels, so that the higher the bell rises the greater is the pressure under which the gas is stored. The pressure of gas in generator has a tendency to drive back level of water below carbide drawer, and the higher the bell rises the lower does the level of water in generator become, owing to the increasing gas pressure.

Producing Acetylene.

Soderquist, R.
Sweden
18943
Sep. 5, 1898

An outer cylindrical vessel united at bottom to inner concentric cylinder provided with a cover. A gas bell slides between the walls of the two cylinders in a seal of water or glycerine. Suspended internally to roof of bell is a perforated carbide holder which passes into a vertical cylinder fitted gastight through the cover of the inner cylinder. Inside this vertical cylinder is a cylindrical vessel with double walls containing within it another cylindrical vessel having its walls perforated at some distance above its bottom. When the gas bell sinks, the carbide holder is lowered into this inner perforated cylinder, which is supplied with water indirectly from an external tank, which is in communication with the inner double-walled cylinder. Generation of gas causes the bell to rise and draw the carbide holder from contact with the water.

Portable Generator.

Hansen, G. and Kraefting, A.
Copenhagen
19106
Sep. 7, 1898

An outer vessel provided with series of holes near bottom is threaded at top to receive screwed lid fitted with gas pipe and burner and stopcock. The upper part of vessel contains a short inner vessel charged with carbide and having a funnel-shaped perforated bottom, the centre of which is prolonged downward

in a short tube. Within the tube is a pipe attached to and extending upwards from the water reservoir below. In the pipe a wick is placed, which has one end terminating in the water and the other in contact with the carbide. The carbide chamber is connected to water reservoir by a gas-tight rubber cylinder. Water passes up wick to carbide, but as the gas pressure increases the intermediate rubber cylinder expands and draws the top of the wick out of contact with the carbide.

Acetylene Generator.

Goodwin, J. S. London 19149 Sep. 8, 1898

The generator consists of a large tray carrying a central reservoir fitted with four metallic wells. The reservoir contains a cylinder, covered by a gasholder capable of rising and falling, provided at the top with a ring, to which is fastened a vertical chain carrying a weight at the lower end. Each well contains a water reservoir, open at the bottom, and a carbide receptacle furnished with perforated bottom. A central vertical pipe extends upwards through the well to the top of the tray. When the holder rises, the chain and weight are raised, allowing water to flow below the level of the carbide. On the holder descending, the weight falls upon the bottom of the external casing, causing water to rise in the side reservoir till it attacks the carbide.

Generating Acetylene.

Boss, J. London 19369 Sep. 12, 1898

The generating chamber is situated beneath a gasholder having a ball valve in the centre of its base. This ball valve is self-acting, and free to rise and fall by the force of unequal pressure from above or below, and allows a free passage for either gas or water from one chamber to the other. In the generating chamber is an inclined floor, upon which the carbide is discharged through a side shoot when the chamber has been filled with water. Beneath the inclined floor is a chamber which is also filled with water, and which communicates with that part of the generating chamber which is above the inclined floor by means of a pipe passed through the highest part of the inclined floor. This lower chamber has a manhole in its base for cleansing purposes, and has also two side cocks, one for emptying the generating chamber, and the other for filling it with fresh water. The automatic closing of the ball valve in the base of the gasholder tank prevents the water in this tank from flowing out when the water in the generating chamber is discharged

Acetylene Lamps.

Marshall, G.
Birmingham
19518
Sep. 14. 1898

The carbide is contained in a perforated cartridge of cardboard or similar material lined inside with absorbent material. A wick passes vertically and centrally through the cartridge, and has its lower end projecting below the cartridge for a suitable distance. The cartridge is placed over a vessel containing water, with its external wick end passing into the water. The lamp contains a suitable upper chamber to receive the cartridge, while the detachable base forms the water reservoir.

Generating Acetylene.

Browett, A.
London
19549
Sep. 14. 1898

A metal cylindrical case, perforated at the top and at the bottom, has some porous material, such as blotting-paper, placed within its lower end, and arranged to admit water but prevent exit of gas. The case is then filled with alternate layers of carbide and porous material. When this case is placed with its lower end in water, gas is generated, and may be ignited at the orifice in the top of the case.

Acetylene Generator.

Waite, T. R.
Bury St. Edmunds
19683
Sep. 16, 1898

Carbide is supplied to a generating chamber by means of a hollow removable plug at the upper end of the chamber, having an opening, so that it may be filled with carbide and then partly revolved before its contents are discharged.

Acetylene Generator.

Robinson, J. V.
Dublin
19674
Sep. 16, 1898

Three vessels of different diameters, each having one end open, are fitted one within the other. The outside vessel, with open top, contains water; the next vessel, with top closed by stopcock, but open at bottom, serves as gas container; while the innermost vessel, with open top and closed bottom, is the carbide holder, and its side is perforated with holes at different levels. When stopcock of gas container is opened, water rises to first perforation and passes to carbide, and if quantity of gas generated is not sufficient, the water rises to second perforation. If generation of gas exceeds consumption, the pressure of gas forces level of water below perforations.

Portable Generators.

Henry, H.
Manningham
19912
Sep. 20, 1898

A generator having a detachable bottom, held in position by a spring device, is claimed. An inner vessel to contain carbide is secured to the detachable bottom. The upper part of the generator contains water, which falls by gravity upon the carbide

Generating Acetylene.

Carbide cartridges are contained in a magazine consisting of a band of ribbon fastened to a hub or shaft. The ribbon is gradually unwound during the operation of acetylene manufacture, and is wound upon a roller on the shaft, round which a lever can be swung. As the ribbon is wound the cartridges are moved downwards into a chute opening into a vessel containing water. The gasholder bell is located below the magazine, and has a guide rod provided with steel points. Each time the bell descends to certain position, these points actuate mechanism, which causes the discharge of a cartridge.

Wallin, B. H. and Wendel, R. de
Gothenburg
20122
Sep. 22, 1898

Acetylene Generator.

The carbide is placed upon a horizontal perforated shelf placed in the middle of a cylinder which is immersed in a water tank. That portion of the cylinder which is below the shelf serves as a gas storage chamber when gas is produced more rapidly than it is consumed. The top of the cylinder is fitted with a cap having a gas eduction tube and stopcock. A cover of gauze is placed over the lower end of the cylinder. The outer water tank is fitted with a cover provided with a vent hole. The generation of gas is regulated by the pressure within the cylinder, as the rise in pressure forces back the water from contact with the carbide.

Dillberg, G.
Sydney, N.S.W.
20430
Sep. 27, 1898

Acetylene Generators.

A water reservoir is formed of two compartments connected together by a valve, the upper compartment being formed to supply the lower compartment with water, while the lower compartment surrounds the carbide chamber and supplies it with water, and serves as a storage and cooling chamber during interruption of gas production. The carbide chamber is a tube open at bottom and closed at top by a cover fitted with a stopcock situated outside the water reservoir. The carbide is placed in an open basket, which in turn is placed within the carbide chamber. The water flows from the lower water compartment up through the open bottom of the carbide chamber to the carbide. The gas passes through the top stopcock to the burner. Increase of gas pressure in the carbide chamber forces back the water from contact with the carbide.

Poerschmann, F. B. and Schneider, H.
Dresden
20541
Sep. 28, 1898

Acetylene Generator.

A lower water tank is provided, within which is another inverted tank of slightly smaller size and capable of freely rising and falling. The carbide chambers are situated at the lower part of the tank. As the gas bell descends it presses upon

Crees, G. W. B.
Trowbridge
20626
Sep. 30, 1898

a float which descends, drawing with it a small bucket. As soon as the upper edge of the bucket is below the surface of the water in the tank, water flows into the bucket, and thence by a pipe into the carbide chamber. The bell rises, and the float carries the bucket to the surface of the water, shutting off the water supply.

Acetylene Generator.

Forrester, W. 20766 Oct. 3, 1898

Upon the top of the pillars, which serve as guides for a gas-holder bell, a water tank is placed, and serves to supply the generators with water. At the upper end of the pipe through which the water flows is a valve which is operated by means of a weighted lever connected with a chain terminating in a weight, which passes through a casing in the tank. As the bell rises its cover comes in contact with the weight, and by lifting it causes the water valve to close. A pipe carries the gas from generator into a water seal and purifier. In the gas-holder tank is a condensing coil through which the gas passes. The generators containing carbide may be inside or outside the holder. An electric indicator to give warning when all carbide is decomposed may be provided.

Regulating the Production of Acetylene.

Turr, R. Paris 20996 Oct. 5, 1898

An apparatus very similar to the well-known hydrogen apparatus employed in laboratories. Carbide, water, and naphtha, or some liquid hydro-carbon, are arranged in the apparatus in such a manner that "the water necessary for the action leaves upon the carbide, as soon as the reaction has taken place, a deposit of the hydro-carbon, the effect of which is inert. A gasholder is not necessary." The action of the water on the carbide is arrested, according to this, immediately the carbide is immersed in the hydro-carbon.

Acetylene Generator.

McConechy, J. Glasgow 21038 Oct. 6, 1898

The carbide receptacle is an oblong rectangular chamber divided along its length into a number of cells to receive carbide. Each cell has a spout leading into adjacent cell. The cells may conveniently be separated by a water-jacketed space. The water flows from the water-jacketed space into the adjoining cell, and from that cell into the next water space, and so on.

Acetylene Lamps.

Barltrop W. P 21576 Oct. 13, 1898

Water chamber above, carbide chamber at base. Carbide container has two concentric walls, the inner one being perforated, while the annular space between the walls is closed with one or more sheets of perforated metal, with or without intervening layers of canvas. About half-way up space formed by inner

wall is a disc upon which drips the water for the carbide. A cover, held in position by a spring above it, is placed over the lower end of the container. The water is delivered in drops from a tube having a pointed end, and passing upward through the water chamber to outside of lamp. The lower part of the tube has perforations one above the other, and an adjustable screw rod closes these holes when it is screwed down, and opens them when drawn upward.

Generating Acetylene.

Van Praag, D. J. London, & Harker, W. Maidenhead 21691 Oct. 14, 1898

The generator consists of a casing containing a cylindrical receptacle for carbide. Above this is a gasholder, provided with water seal; and above this again is a water reservoir, in which the water level is kept constant by a ball float. Through a stuffing box in the water reservoir a tube slides, gas tight, and attached to the top of the gas bell beneath. The tube is prolonged through the bell, and slides in another vertical tube fixed to the base of the holder. The upper part of the first tube is surrounded by a perforated cylinder, upon which rests a weighted cap. When the bell rises carrying the tube with it, the weighted cap is lifted from its support, preventing the further supply of water to the carbide or escape of gas from the holder. The generator communicates with the gasholder by a vertical pipe fitted with stop valve and non-return valve. A blow-off safety tube is also fitted. The carbide is placed between the perforated top of the carbide receptacle and an unperforated disc pressed up by a spring, thus keeping the carbide in contact with the moist pad of lime formed under the perforated top.

Generator.

Schneeweis, J. Hanau-on-Main 22110 Oct. 20, 1898

A reservoir nearly filled with water has a sloping bottom and a sloping overhead partition, which serve as guides for the passage of the carbide. A passage between the two approximate ends of the partitions has a flat valve or door, operated when required from exterior of generator. The door opens into the water chamber, into which the carbide slides, and which has at top a gas eduction pipe. The carbide is fed to the generator by hand. At base of sloping bottom is a sludge discharge cock. The water may be charged with any substance which prevents freezing.

Generating Acetylene.

Williamson, A. D. London-derry 22272 Oct. 22, 1898

Apparatus comprises generator, condenser, double purifier, and storage gasholder. The generator consists of a tank filled with water, in which is a gas bell free to rise and fall. The bell carries the carbide cage within it. In top of gas bell is an opening surrounded by grooved annular flange, which serves as

water seal for equally deep outer tube of charging vessel. This vessel is cylindrical and has near its bottom a transverse partition, and near its upper end another similar partition. The space between partitions is air-tight. Beneath lower partition is a cross rod to which carbide cage may be detachably connected. Water is placed in seal and above top diaphragm. When carbide cage touches water in tank, gas is generated, and bell with carbide cage rises. When consumption exceeds generation, bell sinks and water again attacks carbide. The gas is led to a washer and condenser, then into liquid purifier containing hydro-carbon oil, and subsequently to dry purifier containing chlorinated lime in upper part, and oxide of iron below. Finally gas passes to storage holder.

Acetylene Lamps.

Schieroni, F. E. London 22341 Oct. 24, 1898

See Patent No. 17269 of 1898. The carbide is contained within a cartridge case having a base flange with an exterior shell of such depth that it may fit, watertight, into lower end of inner cylinder. A wick extends centrally from upper part of cartridge down through base, and dips in the water contained in outer cylinder. The cartridge has removable stoppers at both ends.

Acetylene Lamps.

Waibel, F. B. New York 22673 Oct. 28, 1898

The water chamber is above the carbide chamber. The bottom of carbide chamber is removable, and the carbide is placed in a receptacle, having at top a perforated plate, and muslin, or similar material, to act as a filter for the gas. The receptacle has also a central perforated tube covered with muslin, and is held in position by a spring pressing upon its upper end. The valve which regulates admission of water to carbide chamber has a spindle passing vertically up through water chamber, and terminating outside in handle. The water passes through bottom of water chamber into a conductor having lateral discharge openings, and also grooved upon the surface, so that the water will follow conductor by capillary action, and pass into central perforated tube.

Acetylene Generator.

Bailey, J. W. & Clapham, J. Keighley 22826 Oct. 31, 1898

Improvements in previous patents. The water for decomposing the carbide is drawn from the vessel in which the acetylene is washed before passing to the holder. The pipe connections are so arranged that acetylene cannot escape through the pipe by which water is supplied to the washing vessel. A number of carbide holders are arranged at different heights, so as to be successively decomposed.

Acetylene Generator.

The carbide is placed in perforated cylinders supported at some distance from the bottom of a water tank by rests. Each carbide holder is covered by a bell so fixed to plates at bottom of tank that water is able to rise within them from the bottom. The fixed bells are covered by another bell which rises and falls within the water tank. When the cock attached to the gas eduction of any of the fixed bells is opened, water rises within that bell and attacks the carbide. The gas passes through a cooling coil to the movable gas bell. Thus the carbide chambers may be brought into use simultaneously or in succession. Instead of a separate fixed bell for each carbide holder, one fixed bell may cover all the carbide holders.

Gilmer, G. A
Paris
23230
Nov. 4, 1898

Acetylene Lamp Generators.

The carbide receptacle is situated in the upper part of the lamp, and is surrounded by a water jacket. The carbide chamber is closed at the top, and provided with a gas pipe leading to the burner. The water reservoir is at the bottom of the lamp, and contains a wick. One end of the wick dips into the water, while the other passes upwards through a wire gauze horizontal partition to the carbide, to which it conveys moisture. The evolution of gas is stopped, and the lamp is extinguished, by withdrawing the moistened wick from contact with the carbide, the withdrawal being effected by turning the water reservoir from left to right, the rotation drawing the wick from contact with the gauze and consequently with the carbide.

Bilbie, J.
and
Drivet, H.
London
18543
Nov. 5, 1898

Acetylene Lamps.

The water receptacle is at back of lamp, and the carbide chamber at the base. The two vessels are connected by rubber pipe. The carbide is placed in a reticulate bag, and the water flows to the bag either direct from the nozzle or after first travelling through a screen, in which the bag may be placed.

Fischer,
O. R.
Germany
23339
Nov. 5, 1898

Acetylene Lamps.

Between the chamber at base of lamp, which contains an open dish charged with carbide, and the water reservoir at the top of lamp, is a cylinder covered by a bell capable of rising and falling in a water or glycerine seal formed between the casing of the lamp and the bell. Water passes through an adjustable valve in bottom of water reservoir down a pipe to a series of radiating downwardly inclined tubes, which distribute it over the carbide. If generation exceeds consumption in spite of adjustment of valve, the excess gas passes into the

Möller,
J. C. H.
and
Schaefer,
W. C. L.
Hamburg
23385
Nov. 7, 1898

bell, which rises and completely closes the valve. If gas continues to accumulate it may escape up a safety pipe to an auxiliary burner, where it ignites by contact with the flame of the principal burner.

Portable Generators.

Thiersant, H. de and Coulson, W. A. 23675 Nov. 10, 1898

The carbide is contained in a perforated holder placed within a cylinder. The cylinder has internal spiral grooves running around it. The grooves have apertures at suitable intervals. An outer jacket is tightly secured around the cylinder, and has a gas outlet pipe at top. The jacket, with its cylinder, is immersed in a chamber charged with water. The water obtains access to carbide through the grooves and apertures.

Acetylene Generator.

Troubetzkoy L. Milan 24002 Nov. 14, 1898

The carbide is placed in a number of receptacles, one above the other. The lower part of generator consists of cylindrical casing provided near lower end with transverse partition. Within casing is cylinder, open at top and closed at bottom, containing another cylinder also closed at bottom and open at top, within which the carbide receptacles are placed. The annular chamber formed between walls of outer cylinder and casing is filled with water. The upper part of generator consists of casing divided by horizontal partition, to form an upper water receptacle, while lower compartment is open at bottom and adapted to enter the annular water seal in lower outer part of generator. Water inlet is so arranged that top carbide receptacle is first attacked, and after carbide in this has been exhausted, the water overflows to next receptacle, and so on. The valve which admits water is attached to lever which is actuated by the bell of a gasholder connected to the generating apparatus. When bell sinks, water valve is opened; and when bell rises, the valve is closed.

Acetylene Generators.

Margulies, P. Odessa 24065 Nov. 15, 1898

Two gas containers are provided, one of which is connected to the burners, and is automatically closed if gas pressure exceeds normal, while the other receives the gas subsequently produced. Water flows from an elevated tank to a generator containing carbide, but when the gas pressure exceeds a certain point it actuates a device which cuts off the water supply, whilst a second regulating device closes communication of generator with the gas container, to which the burners are connected. A modification of this generator is adapted for railway carriage lighting.

Generating Acetylene.

A water tank has a gas bell fitted within it, and within the bell is another water tank so placed that when the bell is in its lowest position it forms a cover over the cover of the tank with little or no intervening space for the presence of gas or air. The inner tank supplies water to the generators. The horizontal cylindrical generators are placed in any convenient position below the water tanks, and are fitted with gas-tight doors. The carbide is contained in perforated or wirework baskets within compartments so arranged that the water decomposes the carbide in one compartment before flowing over into the next. Suitable pipe connections and stopcocks and valves are arranged between the different parts. When the gas bell rises, the flow of water ceases; when it sinks, the water again flows to carbide.

Beech, W. W. and Jones, H. Stockport 24409 Nov. 18, 1898

Acetylene Generator.

Water flows by gravity into a generator containing carbide. The acetylene is conducted to a gasholder bell, the rise and fall of which connects and disconnects the water supply to the generator. The carbide is placed in a tin receptacle partitioned off with clearance spaces within the divisions.

Ellen, W. Manchester 24501 Nov. 21, 1898

Acetylene Generator.

The gasholder bell in its descent releases carbide cages, which are pivoted one above the other at the side of the feed arrangement. The sludge can be removed without interfering with the working of the plant.

Falbe, O. Berlin 24682 Nov. 22, 1898

Acetylene Generator.

By means of a rotating fan, gas or air is drawn through a vessel filled with porous material saturated with water, then passing through another chamber containing carbide on a perforated tray. By repeating this process, dry acetylene is produced from the carbide without allowing liquid water to come in contact with the carbide.

Lanchester, F. W. Birmingham 24771 Nov. 23, 1898

Generating Acetylene.

A number of cylindrical generators containing carbide are attached to a tank divided by a horizontal partition. A pipe extends from bottom of upper chamber nearly to bottom of lower chamber. A suitable pipe conveys water from the lower chamber to the generators. The lower chamber is supplied with water from the upper chamber, which is a water reservoir. The gas from generator escapes into upper part of lower chamber, and as the gas pressure increases the level of water is

Bailey, C. J. and Nicklin, J. H. Manchester 24785 Nov. 24, 1898

forced back until it is below the inlet of the supply pipe to generators. The retreating water escapes into the upper chamber. The generators are used successively, the water from one overflowing into the next. The carbide holder consists of a series of shallow cases fitted one above the other upon a central removable spindle. Each case is open at top, and has two or more division plates, the water inlet to each division being at a different level.

Acetylene Generator.

Schwass, A.
Berlin
25016
Nov. 26, 1898

The carbide is packed in receptacles successively brought into action. The water supply is governed by the movement of the gas bell.

Generating Acetylene.

Bucher, P.
Mannheim
25297
Nov. 30, 1898

The carbide is placed in a perforated receptacle, which can be passed into, or removed from, a generator open at base and closed at top, by aid of a rotatable lever. For continuous working, two or more such removable carbide receptacles may be employed. The apparatus may be worked by hand or be automatically operated by the rise and fall of a gas bell.

Portable Generators.

Thubron, D.
Scarborough
25227
Nov. 30, 1898

In portable lamp the flow of water from upper chamber is regulated by external stopcock. The carbide in lower chamber is contained in removable cage. A pipe passes from upper part of carbide chamber through water chamber to stopcock and burner. In a larger generator the carbide is contained in a scoop in generating chamber at bottom of gasholder tank, and water is automatically sprayed over carbide when bell descends to certain position. The gas passes through water trap, and then up through any suitable filtering material. In another form the carbide is placed in perforated tube suspended within bell of gasholder, and when bell rises the carbide tube also rises from contact with water. In a floating light for fishing purposes the carbide is placed within a buoy perforated at bottom. The gas pressure within the buoy automatically controls inlet of water.

Generating Acetylene.

Goodwin, J. S.
London
26628
Dec. 16, 1898

An outer cylindrical casing is divided horizontally by a partition near the bottom. Immediately above the partition a number of circular openings are made in the side of the casing. Cylinders to hold carbide receptacles are fitted inwardly through these openings; they are placed horizontally and radially, and are closed at inside end. Upon the end fitted outside the case they are provided with removable covers. Perforated receptacles,

closed at one end and having removable covers, and charged with carbide, are placed within the cylinders. Pipes extend from top of one cylinder to bottom of adjacent cylinder. The first cylinder is in communication, by a pipe passing through the partition, with the lower part of the lower compartment. Water being admitted to the upper part of the casing flows through a pipe to the lower compartment, driving the air out through the carbide chambers. The water rises and gradually enters lowest cylinder, and subsequently enters the other cylinders in succession.

Acetylene Generators.

Apparatus includes a supply chamber for carbide and means for measuring and delivering a given quantity of carbide into a water chamber. Also means for automatically controlling the delivery of carbide, and a cut-off or separator located between the water in the water chamber and the carbide-feeding mechanism, whereby moisture from the water chamber is prevented from rising to the carbide. 12 different claims.

Gardner, E. P. and Kelly, T. New London, U.S.A.
26862
Dec. 20, 1898

Producing Acetylene.

The generator containing carbide is placed beneath a gasholder, the water for the generator being supplied from the gasholder tank, and automatically connected and disconnected by the rise and fall of the bell, which actuates a suitable rock lever and valve situated at the bottom of the holder tank. The generator must not be more than half filled with carbide, as the carbide in decomposing will double its volume. This fact is made use of to cause a perforated plate placed upon the carbide to rise and actuate the counting wheel of a meter fitted near the base of the gasholder tank to indicate how much carbide remains undecomposed.

Friebel, E. and Nake, R. Dresden
27326
Dec. 27, 1898

Acetylene Lamps.

The upper reservoir containing water is detachably connected with lower chamber containing carbide. Claims relate solely to method of connection, the connecting part being formed in one piece of material with the water reservoir. The attachment of carbide chamber is effected by stirrup piece hinged on one side and secured on other side by lever catch. The stirrup piece presses against bottom of carbide chamber, and is provided with a regulating screw for compressing the packing material.

Schmitt, L.
27618
Dec. 31, 1898

Acetylene Generator.

Three superposed chambers, the bottom containing water, the middle containing a carbide feed-hopper, and the top one containing a loaded gas bag for regulating the feed of carbide. As

Beck, C. W. Chicago
636
Jan. 10, 1899

the gas bag collapses, the feed plunger descends and allows carbide to pass, and as the bag becomes inflated it draws up the plunger and closes the feed aperture. To prevent splashing of water when carbide drops into it, a cork float is suspended in the water chamber, and has holes through which water may pass up through it. An expansible bag is fastened to mouth of water chamber and to the edge of the float. The carbide drops upon the float, and as it accumulates weighs down the water below the water surface. When all the carbide has been decomposed the bag and float containing the residue can be removed.

Acetylene Generators.

Seiffert, E.
Prussia
and
Tomlinson, J. D.
Rochdale
682
Jan. 11, 1899

7 sheets drawings, 7 claims. A carbide receptacle provided with internal pockets, arranged radially and spirally, is placed within a cylinder. The interior space within the receptacle is in communication above and below with water pipes, through which is conducted a constant stream of water to cool the receptacle. The water for generation of gas is admitted through a pipe into annular perforated pipe at upper end of cylinder. The perforated pipe directs water against inner wall of cylinder, down which it runs. The gas rising from carbide passes through pipe to a dip pipe, which delivers it below the water of a gasholder. Automatic control of gas pressure is obtained by means of a float valve working in a water cistern. A gasholder is also described, which consists of two or more tubes having a common gas exit, but insulated by wire gauze to prevent communication of explosions.

Acetylene Lamps.

Electro Lamp Co.
New York
707
Jan. 11, 1899

Water chamber at top, and carbide chamber at base. Between the chamber is a screw-threaded channel with a conical opening to receive end of needle valve. The needle valve is adjusted by turning a perforated tube, which passes upward through the water vessel, and terminates in a perforated funnel, fitted at top with a milled perforated head outside the casing. The perforated tube is surrounded with cloth or other porous fabric. The carbide container has a removable top and removable bottom. A vertical perforated tube secured to the bottom extends through the centre of the container. The water from reservoir enters this tube, which may be filled with filtering material, and passes through perforations to carbide. Within the container is a horizontal disc supported from the top by a spring. This spring is adapted to compensate for the swelling of the carbide beneath the disc. Absorbent discs are placed against top and bottom surfaces of the carbide.

Acetylene Generator.

One end of a cylinder fitted with a piston opens into the generator, one end of the piston being acted on by the gas in the generator and the other by a helical spring. When the volume of gas in the generator decreases, the piston is forced inwards by its spring until a rod attached to it comes in contact with a sliding valve at the bottom of a vertical carbide chamber. The valve being thus opened, carbide falls into the water in the generator. With the increased volume of gas, the piston is forced back closing the carbide chamber.

Hillberg, E.
Berlin
1796
Jan. 26, 1899

Acetylene Apparatus for Railway Cars.

A cylindrical casing containing an inner water reservoir and carbide holder, divided into compartments which are attacked successively as required. The outer casing also serves to store the gas before it passes to the burners in the car.

Duderstadt, F., & Kandler, M.
Leipsig
1809
Jan. 26, 1899

Generating Acetylene.

A rectangular metal vessel is divided at about half its height by a horizontal partition. The upper chamber of the rectangular vessel serves as a water reservoir, the lower as a displacement gasholder. Passing across the interior of the gasholder is a rectangular chamber so constructed that it is hermetically sealed from the gasholder, save at point where water enters and gas escapes. The chamber is inclined and closed by a gas-tight door projecting slightly beyond wall of gasholder. The trays containing carbide are inserted through this door. Each carbide chamber has near top a perforation, all the perforations being at a different level. When the water rises to level of lowest perforation, gas is generated and passes through washer to top of gasholder. Increase of pressure beyond certain point prevents flow of water to carbide. A gauge, to show by height of water which carbide vessel is in action, is provided.

Bond, E. S.
Handsworth
2186
Jan. 31, 1899

Portable Lamps.

The water reservoir is immediately beneath the carbide holder, which latter nearly fills the gas chamber in which it is contained. A central tube rises through reservoir, and within it is a wick tube capable of being moved up or down by a cam and shaft connected to an operating button outside bottom of reservoir. A cap is also screwed to top of shaft, so that when operating button is turned the cap is moved over top of central tube simultaneously with the lowering of the wick tube, or turned away from top of tube when the wick tube is raised. The details of construction may be largely varied. Gas is generated by contact of top of wick with carbide.

Rhind, F.
Bridgeport
U.S.A.
2226
Jan. 31, 1899
Cl. July 22, 1898

Acetylene Generator.

Schneeweis, J. Hanau, Germany 2392 Feb. 2, 1899

Carbide falls into water. The carbide is placed in a series of chambers circularly arranged, the bottom plates being opened successively by a rotating plate operated by the descent of the gas bell. In the water vessel, into which the carbide falls, is an inclined tubular shoot having an orifice which can be closed, so that the carbide may be introduced by hand when desired.

Acetylene Lamps.

Barratt, F. W. Wimborne 2699 Feb. 7, 1899

The use of a double water supply chamber is claimed. Preferably one chamber is above the other. The carbide chamber is attached to base of lower water chamber. A tube passes from bottom of upper water chamber down through lower water chamber. The end of tube is bent upward so that its mouth opens in the lower water chamber near the bottom. The water from top chamber passes to lower chamber to replace that consumed in gas generation. Water is introduced through openings normally closed with perforated screw caps. Gas pipe from carbide chamber may pass through both water chambers to burner.

Acetylene Generator.

Szepczynski, S. de Vienna 3551 Feb. 17, 1899

Carbide is fed into water by drums operated by a gasholder bell, and divided into cells which are emptied in succession. A number of annular receptacles are arranged to surround an inner drum, and as each receptacle is emptied, it carries along the adjoining charged receptacle. Each time a receptacle is discharged by sinking of the bell to certain position, a charged receptacle is simultaneously brought over the feed aperture.

Acetylene Generators.

De Lasserve Isaac France 4054 Feb. 23, 1899

Two or more bells, each containing a cylinder perforated in the upper part and holding trays loaded with carbide, are so connected to a gasholder bell that when all are immersed together in the same tank of water the ascent of the gasholder bell withdraws the carbide bells from the water at the same time.

Acetylene Generators.

Caldicott, J. Hull 4115 Feb. 24, 1899

Within a gasholder tank there rises a vertical pipe provided with a packed gland. Within this pipe slides a pipe vertically suspended from the top of the gas bell, and having water inlet holes perforated in it at a certain distance from the top of the bell. The generators containing carbide are externally connected by suitable pipes and cocks to the gasholder, from the tank of which they are supplied with water when the gas bell

sinks sufficiently to allow the perforations of the depending pipe to fall below the water level. When the bell rises sufficiently to draw the perforations above the water level, no water can flow to the generators.

Portable Generators.

A cylindrical casing is mounted upon a detachable water reservoir. Within the casing, and separated from water reservoir by a partition, is an annular secondary chamber partly filled with water, and constituting a water seal for a bell. Within the bell is a cylindrical chamber, having its bottom open to water reservoir, and its top furnished with a neck opening into upper part of bell. This cylindrical chamber receives a detachable carbide holder, having a sleeve at bottom, which fits into neck of water reservoir. The lower end of carbide holder is closed by a conical valve operated by a rod extending up through the holder, and kept up to its seating by a spring in the upper neck of carbide holder. The interior of carbide holder is formed into a series of hopper-shaped compartments, one above the other. When generation exceeds consumption, gas passes up to bell, which rises and allows the spring-operated rod to close carbide feed valve. When bell sinks, it presses down the rod and spring, and opens the valve. Gas eduction pipe passes up through top of annular chamber, where connection is made with flexible tubing, which conducts it to burner. The burner is fitted on top of detachable lid of casing.

Sunderland, R. H. and Marshall, G. Birmingham
4093
Feb. 24, 1899

Acetylene Lamps.

Amplification of Marshall's Patent No. 19518 of 1898. The cartridge case is lined internally with absorbent material, and has an internal domed false bottom. The domed bottom is provided to allow room for the expansion of decomposing carbide, and may be constructed of the absorbent lining material, or any other compressible substance. The wick, which passes through the cartridge and hangs below its base, is now weighted at the end suspended in water.

Sunderland, F. and Marshall, G. Birmingham
4087
Feb. 24, 1899

Generating Acetylene.

Carbide falls into water. A vertical shaft rises through the centre of a generator connected with a gasholder. The shaft passes through the bottom of the generator, where it is connected to a fixed pulley round which a chain or cord is passed. The fall of the gasholder causes the pulley to rotate to a certain extent. The top of the shaft terminates in a disc provided with one or more slots. On the rotation of the shaft by the descent of the gasholder, the pin which fastens the hinged bottom of

Berger, H. Berlin
4223
Feb. 25, 1899

a carbide receptacle is withdrawn, allowing the carbide to fall into the water. The carbide boxes are segments of a circle in cross section with hinged bottoms.

Acetylene Lamps.

Haws, J. R.
Liverpool
1560
Mar. 2, 1899

The lamp has a hollow base, into which is placed a wire cage charged with carbide, and provided with a spring, which presses the carbide upward. Around the base is an annular space filled with water to form a water jacket. Above the base is a water container having a cylinder, which dips into the water in the annular space, depending from its under side. Upon the upper side of the bottom of the container is a gas chamber secured by a bayonet joint. Small holes are provided in side of gas chamber near bottom. A pipe extends from centre of top of carbide chamber up into the gas chamber, and has a small side hole above bottom of the gas chamber. A stop-cock and burner is situated on top of gas chamber. When container is charged with water, the water flows into the gas chamber, and through the hole in central pipe, from whence it drops to carbide. The gas escapes up central pipe to gas chamber, and as gas pressure increases the level of water is driven back until it ceases to flow through hole to carbide.

Acetylene Lamps.

Riemann, A. H. and H. O.
Saxony
5090
Mar. 8, 1899

Relates solely to devices for securing carbide holder contained within a case to the underside of the body of an acetylene lamp. A flange extends downward from lower part of lamp body, and the carbide holder case has two flanges provided with inter-hooking parts engaging as bayonet joint. Through bottom of case a screw extends upward to press carbide holder against packing material in seating of lamp body.

Acetylene Lamps.

Dolan, E. J.
Philadelphia
5221
Mar. 9, 1899

Three superposed compartments: the top to contain water, the middle to contain carbide, the bottom to receive carbide residue. Between middle and bottom chambers is a rotatable grate operated by a spindle extending outside. This grate supports the carbide, and when rotated detaches the residue from the undecomposed carbide, and distributes the carbide so that fresh surfaces are constantly exposed to the water. The water passes through a valve in bottom of top chamber, but instead of falling direct upon the carbide is made to flow along a flexible conductor, in the form of one or more small chains, so that it reaches carbide in steady stream. Within the middle chamber is an inwardly extending finger, the lower end of which approaches the rotatable grate, and retards movement of carbide

when grate is rotated. The spindle may pass through the base of the bottom chamber, and terminate in a hand-wheel large enough to form a base for the lamp.

Generating Acetylene.

Fröhlich, B.
Leipzig
5614
Mar. 15, 1899

A containing vessel has a bottom provided with a downward cylindrical extension. Within the extension is the holder containing carbide, the holder being normally forced upwards by a spring beneath it. The lower portion of the containing vessel is filled with a heavy liquid such as chloroform or carbon disulphide, which must be unattacked by carbide or acetylene. Upon this layer of inactive liquid is placed a layer of water. The spring forces up the carbide holder so that the carbide is in contact with the water. If production exceeds consumption, the gas pressure forces down the carbide holder below the water level and immerses it in the inactive liquid.

Acetylene Generator.

Sunderland, R. H. & F., & Marshall, G.
Birmingham
6274
Mar. 23, 1899

The generating chamber at the base of the apparatus is a double cone-shaped compartment surrounded preferably by an outer casing, and terminating at the bottom in an outlet for spent lime, etc. The upper end of the generator is surmounted by a fixed carbide holder in a cylindrical casing. A valve stem passes out through the top of the carbide chamber, and has a head or button at the upper end, between which and the top of the chamber a spring is placed, the tendency of the spring keeping the valve up on its seat when the gas-containing chamber, located around the carbide chamber and working in a water seal in the outer casing of the apparatus, is raised by the generated gas. When the holder falls, the top of the container strikes the top of the valve rod, compressing the spring and opening the valve, thus allowing carbide to fall into the water in the generating chamber. The gas is cooled by passing through a worm in the gas container.

Acetylene Generators.

Robinson, J. W. and Hadley, H.
Enfield
6328
Mar. 23, 1899

Each generator is provided with a carbide bucket, and has at top a non-return gas valve. The generators are covered by movable bell, and the whole is contained in a closed tank filled with water to suitable height. The closed tank communicates with a superposed water reservoir. When bell is in lowest position a valve at bottom of superposed reservoir is held open by spring, and water passes down a pipe to the generators. The pressure of gas generated first commences to force water from bell up into superposed tank, but soon the bell rises, and when it nearly reaches top of closed tank in which it is contained, it raises a plate and lever, and thereby closes valve

which admits water to generators. Gas generated after water supply is cut off merely tends to force water from closed tank up to overhead tank. One generator may be cleaned while others are in operation.

Acetylene Lamps.

Hedgeland, F. W.
Chicago
6602
Mar. 27, 1899

The carbide is placed in a cylindrical holder open at bottom and closed at top by a removable cap having a gas eduction tube passing through its centre. The carbide holder is placed within a chamber in the body of the lamp, the chamber being surrounded by the outer casing containing water. Beneath the carbide chamber is an equalising chamber which has an inclined pipe passing from bottom annular passage of water reservoir nearly to its base. The water inlet from annular passage to equalising chamber is controlled by valve having stem projecting through top of reservoir. Through centre of carbide holder a tube passes vertically, the upper portion forming gas eduction pipe, and lower part, which is enlarged in diameter and is perforated, serves as water inlet. Reservoir being filled with water, water passes into equalising chamber through valve and rises to the enlarged perforated part of tube. When production exceeds consumption, pressure of gas forces back the water to equalising chamber.

Acetylene Generator.

Combier, A.
Pierre
Benite
France
6925
Mar. 30, 1899

The generator is formed of a double reservoir with a single bottom, the interior one receiving the water to act on the carbide, and the exterior containing the gasholder bell. The carbide hopper is attached to the dome of the bell. A rod carrying two spherical valves passes through the mouth of the hopper. When the bell rises beyond a certain position, the upper spherical valve closes the mouth of the hopper; and when the bell falls, the valve is raised from its seat, allowing carbide to drop into the water.

Acetylene Lamps.

Thinault, A. E.
and
Dreyfus, M.
Paris
7099
Apr. 4, 1899

The carbide is placed in suitable holder in carbide chamber, which in turn is situated within a reservoir charged with water. The carbide chamber carries cap with burner. A metal tube, sufficiently thick to absorb heat arising from carbide decomposition without conducting it to the water, passes vertically through centre of carbide holder. The tube is slotted for certain portion of its height to allow water to pass to carbide. A threaded rod passes down the tube, leaving a small annular space for water passage. The rod is screwed into collar at lower end of slotted tube. The rod is preferably provided with several threads, so that the water rises as if in several capillary

helicoidal tubes. In another form of lamp the rod is not threaded, but is arranged within a perforated tube, leaving slight play between rod and tube.

Generating Acetylene.

Read-Holliday Acetylene Co. Cardno, W. and Read-Holliday Huddersfield 7325 Apr. 7, 1899

Apparatus consists of two detachable parts. The lower part has a container for carbide and residual lime, and serves as a gasholder. The upper part is a water reservoir having a number of valves or taps through which water cannot pass more rapidly than in drops. The gas producing capacity of generator is proportionate to number of valves. Each valve can be operated independently of the others.

Acetylene Lamp.

Andersen, A. P. Copenhagen 7400 Apr. 8. 1899

The water reservoir is at base of lamp, and its bottom is constructed of rubber. Carbide is contained in a grid in a cylindrical chamber above, and at top of this chamber is a rubber gas bell. The rubber chambers at top and bottom of lamp are protected by suitable perforated metal guards so constructed as to allow space for expansion of rubber. When pressure of gas rises owing to shutting burner cock, or to excessive production, the rubber bottom of the water reservoir is pressed downwards and the level of water sinks below the carbide grid. The gas, which may then continue to be slowly evolved, passes into the rubber bell at top of carbide chamber, and any gas produced after this is filled may escape through a safety valve to open air. The gas passes through a tube containing some suitable filtering and drying material. When gas pressure is relieved, water returns to the carbide.

Generating Acetylene.

Demuth, C. Zittan, Saxony 7877 Apr. 14, 1899

A drum for holding the carbide, divided into several compartments, is fitted immediately above a water container connected with a gasholder. Between the gas bell and the weighted drum is a ratchet, which causes the drum to move to a certain extent at each movement of the bell. The charges of carbide thus automatically released by the rise and fall of the bell pass into the hopper of the water container, and are deflected by a cone to the sides of the vessel, to prevent the residue accumulating in the centre of the vessel.

Acetylene Generator.

Küppers, K. and Schroeder, H. Aix-la-Chapelle 8339 Apr. 20, 1899

A funnel-shaped carbide receiver, closed at top, has an aperture at bottom, which can be closed or opened automatically by a valve, operated by an annular float by means of a lever. A pipe attached to bottom of carbide receiver passes down into an open vessel arranged within a water container. The float in

lower part of open vessel is connected with vertical lever, which actuates carbide feed valve. Below valve is a conical shield to prevent scattering of falling carbide. The gas eduction pipe is connected to a small pipe extending upwards to top of carbide receiver. A device to indicate the amount of carbide in the receiver is fitted in receiver cover. When carbide drops into water, the pressure of gas generated forces down level of water and with it the float, thereby causing feed valve to close. As pressure diminishes, float rises and opens valve. The bottom of water container being funnel-shaped, and provided with drain pipe and cock, the removal of sludge is easily effected.

Portable Generator.

Boettcher, O.
Charlottenburg
8765
Apr. 26, 1899

The carbide holder is adjustably suspended in a water receptacle by means of its vertical gas outlet tube. In bottom of carbide holder is a spring-pressed valve having a stem with a conical top projecting upwards above the carbide. When the holder is lowered into the water to a certain distance a very fine jet of water passes up through the valve to the carbide. Gas is generated and passes to burner. As the gas pressure in the holder increases, it drives back the water and checks generation.

Acetylene Generator.

Deike, A. H.
Alexander, W. A.
and
Mitchell, J.
Guelph, Canada
9743
May 9, 1899

Two carbide holders, each having a bottom portion divided into a series of sections hinged to the body of the holder, are located above a water reservoir. The successive discharge of the contents of each section is automatically effected by the repeated descent of a gasholder bell to a certain point.

Generating Acetylene.

Steiner, L.
Bucharest, Roumania
10152
May 13, 1899

The carbide receptacle is situated within a displacement gasholder, and can be removed from below or from the side. The holder is surrounded by a water tank, the two communicating with each other through holes in the lower part of the gasholder. A safety blow-off pipe is provided for the escape of gas when the pressure is excessive. Above the water tank and gasholder is placed a water reservoir, from which, by means of a valve operated from the exterior of the reservoir, water is allowed to drip upon the carbide. The acetylene passes through pipes from the generating chamber to the gasholder.

Acetylene Gas Generators.

Steiner, L.
Bucharest
10151
May 15, 1899

A bell with carbide holders fitted within is immersed in a water tank. The carbide holders are provided with water inlet openings, placed at various heights, in order to prevent the whole of the carbide being acted on at once, and to avoid over production of gas.

Generating Acetylene.

Carbide falls into water. The carbide rests against a special form of valve in the generator, the seat of which rises or moves at the required moment, allowing a certain quantity of carbide to fall. The device may be attached to the bell of a gasholder or to generators separate from the holder.

Tabard, G.
Lyons
10410
May 17, 1899

Generating Acetylene.

The generator is shaped like an inclined funnel, and can be turned round on a pivot for cleaning purposes. The upper opening of the generator is immediately beneath the discharge end of a carbide shoot. The shoot is arranged in a spiral round the gas bell, and in it are placed balls of carbide or iron balls filled with carbide. When the bell is in a certain position a fork attached to the bell enters the shoot above the lowest ball. On the bell still sinking, a rod disengages the catch which closes the end of the discharge pipe, and allows the ball to fall into the water in the generator.

Saule, P. C.
Tulle,
France
10862
May 24, 1899

Generating Acetylene.

A generating device formed by a spiral or worm inside a sieve casing. In the worm, or on the casing, are fixed claws or pins to effect the continuous sifting, turning, and distribution of the pieces of carbide, in order to free them from the coating of lime. At the same time, cold water is directed by means of jet pipes upon the carbide, and this water washes the surface of the carbide, cooling and purifying the gas as it is liberated. As an alternative, a conveying worm may be arranged under the generating device to move forward continuously the lime sludge that sinks down.

Fenderl, E.
Vienna
11116
May 27, 1899

Acetylene Lamps.

Acetyloid, which is "a combination of calcium carbide with other substances which make it impervious to moisture," is placed in a wire basket, which in turn is placed in a fixed bell. This bell has at top a tubular extension terminating at top in stopcock and burner. The tubular extension is divided into chambers, the lower containing carbide to dry the gas, the intermediate with purifying "chemicals," and the top chamber with cotton wool. The bell is lowered into a cylindrical vessel half filled with water, and covered at top by lid attached to tubular extension of bell. When gas generation exceeds consumption, the pressure of gas forces water away from contact with carbide.

Worsnop,
C. H.
Halifax
11135
May 29, 1899

Portable Lamps.

Hilberg, E.
Berlin
11494
June 2, 1899

The water tank is at base of apparatus. The carbide is placed in a receptacle within a vertical cylindrical chamber having its lower end opening into the top of the water tank. The carbide outlet is closed by a valve consisting of two rubber semi-circular discs, having the straight edges arranged opposite each other, and the circular edges secured to the mouth of the receptacle. A complete disc of rubber, having a slit along its diameter, may be substituted. The valve is opened by a spindle, which is forced down by a spring in the top of the lamp. Attached to spindle is a flexible diaphragm, which is forced upward against spring by pressure of gas, and withdraws the end of spindle from the valve, and thus permits it to close and stop feed of carbide. When gas pressure falls, the pressure of spring again causes spindle end to open carbide feed valve. The gas passes upward through a filter, and through a passage formed in valve spindle, to the burner. A tube passes from bottom of water reservoir to a stopper in upper side of lamp. If gas pressure becomes excessive, the water is forced up this tube, pushes out the stopper, and escapes, leaving lower end of tube open also for escape of gas. Carbide which falls into water chamber when water is at low level is caught upon the perforated top of the sludge receptacle.

Acetylene Lamps.

Morin, T.
and
Straguin, A.
Paris
11551
June 2, 1899

The upper water reservoir has a cylindrical top closed by a screw plug. In side of cylindrical top is an aperture for admitting air, which may be completely or partially closed by a rubber ring around it. The opening at bottom of reservoir is fitted with a porous plug through which water falls, drop by drop, upon an inclined plate in chamber beneath, and from thence flows to horizontal cylinder containing wire basket charged with carbide. The gas escapes through a chamber containing filtering material on top of carbide cylinder. After filtration, the gas passes to burner. In carriage lamp, water reservoir is at back of lamp, and communicates with lower carbide chamber by a tube with porous plug. The water drips upon carbide, and gas escapes down into a tubular gas chamber and up through a depending tube charged with flannel or other filtering material and up to the burner. The bottom of the lamp holder is a tubular detachable collector for the condensed water.

Acetylene Generator.

Nowak, G.
and

The carbide receptacle has a bottom provided with a number of vertical conical tubes, through which water rises so as to

attack the carbide from the top downwards. The carbide receptacle is suspended in bell of gasholder. The gas eduction pipe leads to a second gasholder, the bell of which is so adjusted that it will rise under a lower gas pressure than will the bell of the generator When generation of gas in the generator causes bell of storage gasholder to rise, the generator bell remains stationary. But when the storage bell has risen to a certain point it automatically closes the gas cock leading from the generator. The pressure of gas in generator therefore increases, and the generator bell rises and draws the carbide receptacle from the water. The wet carbide will still continue to evolve gas for a time, but this may escape to the storage bell through a specially provided gas-way. When storage bell sinks, the main inlet gas cock is automatically opened, and as the pressure in generator bell is relieved, the bell sinks and again immerses carbide receptacle in water.

Klemm, P. Austro-Hungary 12659 June 17, 1899

Acetylene Generator.

A generator tank containing water, a gasholder, and a method of causing the holder to feed charges of carbide to the tank. The specific claims are: Novel method of feeding the carbide to the water; an arrangement between gasholder and feed-wheel for actuating the latter at the proper time and position by the holder; novel methods pertaining to the generator tank, and for controlling and delivering the gas to the holder, whereby the waste can be withdrawn without interfering with the apparatus.

Goldbacher, J. N., New York, & Bournonville, E., New Jersey 13301 June 27, 1899

Acetylene Lamps.

The casing is open at bottom but closed at top by a dome cover, which serves as a gas reservoir. A vessel closed at bottom but open at top is detachably fitted in the casing, and contains a cylinder closed at bottom but open at top, and supported by horizontal partitions in the containing vessel. In the cylinder, which is surrounded with water, is placed the carbide holder, which has a small perforation in its bottom, through which passes the lower end of a small vertically slit feed water tube. Below the cylinder is an air chamber. The water, when allowed to pass the valve, enters the air chamber, but the flow is soon checked by compression of air therein. Sufficient water will however enter to rise through the inlet to carbide chamber and up the slit tube. The generated gas escapes to gas reservoir, then down a pipe to cooling chamber and then to burner. The flow of water to carbide is automatically regulated by the pressure of gas within the lamp.

Pauli Lamp Co. Chicago 13339 June 27, 1899

Acetylene Generator.

Sunderland, A. H. & F., & Marshall, G. Birmingham 13786 July 4, 1899

Improvement of Patent 6274 of 1899. The objects are to improve and simplify the construction of the apparatus in such a manner that the escape of gas is prevented. The apparatus may be re-charged with carbide while in operation. The liability to explosions is minimised, and the generated gas is cooled and purified before being conveyed to the holder.

Generating Acetylene.

Wilson, F. C. Chicago 13805 July 4, 1899

Claims: The employment within a generating chamber of one or more floating carbide containers, and so arranged that the water gains access to the carbide as gas is required, whereupon the vessel sinks and immerses the carbide; arranging a series of buoyant carbide containers with means for limiting their upward flotation, the water inlets being at different levels —thus each carbide vessel is attacked in succession; arranging means whereby the carbide holders are held with their inlets at different levels, so that they are successively lowered according to the demand for gas; arranging the carbide receptacles in a removable pan or drawer within the generating chamber and communicating therewith.

Acetylene Generators.

Lacroix, P. Paris 13924 July 5, 1899

Relates to a device to enable water to flow to two generators simultaneously immediately one of them becomes exhausted or becomes inadequate to supply the volume of gas required. The device consists of a water distributor attached to a syphon tube connected to an elevated water tank. The distributor communicates by a pipe with a variable-pressure gasholder, and has three cocks communicating with one another. The central cock regulates admission of water to distributor, and the side cocks permit or prevent its flow to the respective generators.

Generating Acetylene.

Hamont, P. Van Belgium 14124 July 8, 1899

Two vertical generators connected to a gasholder contain superposed trays charged with carbide. The bell of the holder is attached to the control valve of an elevated water tank. When the bell sinks, the connecting rope becomes taut and opens the valve; and when the bell rises, the rope slackens and the valve closes. The water rises from the bottom of one generator to each tray in succession; and when the carbide in all the trays in one generator has been decomposed, the water overflows to the next generator.

Generating Acetylene.

This invention is to render the use of stuffing boxes in acetylene generators gas tight, by maintaining a bath of oil at the back of the box on which the pressure of gas is exerted. The generator is a cylinder hermetically closed, and filled with water to a certain level. Powdered carbide is placed in a hopper above the generator, and above the hopper is the oil box. The shaft passing through the stuffing box serves to actuate the valve by the movement of the gas bell.

Quelle, E.
Paris
14240
July 10, 1899

Acetylene Generator.

Carbide in measured quantities is automatically discharged into water. The carbide containers are fixed on the lid of the water receptacle, and the contents of each are discharged, when the gas bell sinks to a certain position, down a shoot into the water. This is effected by a toothed wheel, within which is arranged a pawl and pawl wheel, which allows the bell to rise without affecting the generating mechanism.

Soderberg, C. W.
Nordstrand, Norway
14499
July 13, 1899

Acetylene Lamps.

The outer case is provided with a hinged cover and contains water in its lower part. Between the water reservoir and the upper carbide chamber is a space in which netting and filtering material is arranged. In the top of the outer case, above the carbide chamber, is a casing containing clockwork. This clockwork rotates a vertical shaft, which causes a conveyer to conduct carbide from its containing chamber into the water. The gas passes through the filtering material and passes up a lateral pipe to the burner. The clockwork is shielded from contact with the gas, but the gas can pass up the central shaft to a shell. If the gas pressure becomes unduly high, certain mechanism is actuated which stops the clockwork and the discharge of carbide.

Gerdes, A.
Berlin
14698
July 17, 1899

Acetylene Lamps.

An inner case contains carbide, and the outer case water. Between the two is a valve controlled by the pressure of gas, admitting water when pressure falls below a fixed point, and cutting it off when pressure rises. The cylinder which contains the valve projects upward centrally into the carbide vessel from its base. The carbide may be contained in a cartridge consisting of two telescopic cups having their closed ends outward. The cups are made annular, having cylinders placed concentric with the outer walls and telescoping in a similar manner. The cylinder which forms a portion of the lower cup has a series of perforations in its sides through which water is admitted to the

Bayley, G. W.
Brooklyn, U.S.A.
14816
July 18, 1899

cup. The cups are provided with a longitudinal groove at one side, adapted to accommodate the pipe within the inner case.

Acetylene Lamps.

Snyder, G. G. and West, M. L. Easton, U.S.A. 14795 July 18, 1899

The carbide chamber is suspended in water reservoir. Within carbide chamber is perforated tube provided with wire gauze jacket. Pipe in top of chamber conducts gas to burner. A plug in lower end of perforated tube is provided with central vertical passage terminating at top in lateral passage, through which water flows to carbide. The flow of water is automatically controlled by pressure of gas within carbide holder.

Cycle Lamp.

Carey, A. M. Middlesbro' 15413 June 19, 1899

A metal tube divided into two chambers, the lower containing carbide, and the upper containing water, which is admitted to the lower by an adjustable valve in the disc between the chambers. The tube is inserted in the handle bars of the cycle. A burner governed by a pin valve is provided upon the front of the handle bars, and this burner is in communication with the gas chamber formed between the internal tube and the internal walls of the tubular handle bars.

Producing and Storing Acetylene.

Bridges, C. M., San Francisco 14984 July 20, 1899

The carbide holder is placed above a cylindrical vessel containing water. When the carbide drops into water the generated gas passes into a perforated drying chamber, through another cylindrical chamber, into the gasholder bell. The production of gas is automatic, but one of the main objects is "to relieve the gas from constant contact with water by providing a novel dry seal and thereby improve its quality and illuminating properties." When the bell is forced upwards by the generation of gas, a rubber sleeve or hood is acted upon and the carbide supply cut off.

Acetylene Lamps.

Bond, E. S. Handsworth 15336 July 26, 1899

The upper chamber is filled with water through an elbow having a perforated screw cap. In the lower chamber is a removable holder charged with carbide and covered with asbestos or similar substance. The water chamber has the burner above it and a stopcock beneath it, the two being connected by a vertical pipe passing centrally through the water chamber. The stopcock has two channels: one for passage of gas, the other for passage of water. The stopcock may be so turned that water is cut off while gas passage is open, or both passages may be either open or closed. The water passes down a vertical pipe sheathed with a tube perforated around top

placed in the centre of carbide holder. The perforated tube carries a horizontal flange extending over the surface of the carbide. Thus some of the water passes to the centre of the carbide, while another portion flows over the flange to the furthermost carbide.

Acetylene Generator.

Bartmann, L.
Berlin
15406
July 27, 1899

A cylindrical chamber is fitted inside another cylindrical chamber in such a way that both chambers are closed at top by the same cover, and the inner chamber is in communication at the bottom with outer cylinder. The inner chamber is provided with a bell which encloses a carbide holder having perforated walls and a conical bottom. The cover of holder is in form of a piston having its rod extending downwards through the carbide and holder bottom, where it is attached to a spring which has its lower end hooked to a suitable part of the apparatus. This spring tends to pull the piston down, and as the carbide is decomposed, to press the residue out of the holder. The outer cylinder is the water reservoir. The gas outlet pipe passes from bottom of inner cylinder to a coil in the outer reservoir, and from thence to burner. Below the bottom of cylinders is an acetone chamber, with which a pipe in the inner chamber communicates. This pipe is bent within the chamber so that its open end is normally below the level of water, which is provided with a layer of oil in this chamber. Gas generated under excessive pressure is absorbed by the acetone.

Portable Generators.

Mottlau, A. J.
Copenhagen
15459
July 27, 1899

The carbide container which forms upper part of generator has an elastic cover, through centre of which a rod passes vertically downward and is provided at lower end with valve which controls vent at bottom of carbide chamber. The rod has an upper screw thread and terminates outside chamber in a nut, by which the carbide discharge valve may be adjusted. When pressure of gas in carbide chamber increases, the elastic cover is forced upward and draws up the valve rod, thereby closing feed valve. When pressure falls, the valve opens. The water chamber which forms base of generator is detachably connected to carbide chamber. The lower part of tube which extends from carbide into water chamber is perforated or of metallic network, thus preventing the splashing of water into carbide feed valve. A gas tube leads from top of carbide chamber down through its funnel-shaped bottom, while another tube leads from top of carbide chamber to burner.

Acetylene Generators.

Hilberg, E.
Berlin
16426
Aug. 12, 1899

See Patent No. 11494 of 1899. Water tank at base. A cylinder is divided by a funnel-shaped carbide feed contrivance into an upper carbide chamber and a lower gas chamber. The lower end of the cylinder dips down into the water in the bottom tank, which has an upward cylindrical extension which surrounds the cylinder, and is furnished with openings at its upper end. The gas chamber formed by this cylindrical extension is in communication with the gas chamber below the carbide feed. The carbide feed valve is a rubber plate split diagonally, or two such plates coming in contact with one another may form a better valve. A rod furnished with a tongue may be worked by any preferred mechanism to open and close the valve. If the lamp be accidentally overturned, the water cannot flow out owing to the provision of some spiral courses between the cylindrical extension and the wall of the inner cylinder.

Acetylene Lamps.

Schad, Herbst & Co.
Mannheim
17195
Aug. 24, 1899

The water reservoir is at top, and has a drip tube terminating in a valve, and depending into the central tube of a lower chamber containing carbide. The central tube is perforated at its lower end. Beneath carbide chamber is a tubular ring, which constitutes base of lamp. When valve is opened, and water flows to carbide, gas escapes to a gas chamber between water and carbide reservoirs, and then passes down a hollow pillar to ring at base, from which it passes to burner. The base of lamp is detachable, to allow of introduction of carbide holder.

Producing Acetylene.

Dauber, A.
Bochum, Germany
17343
Aug. 26, 1899

Carbide falls into water. A device to prevent the distribution of the carbide over the whole area of the bottom of the water tank, thus preventing the escape of gas between the tank and gas bell. When the bell sinks to a certain point, carbide is automatically discharged upon a spiral, and falls into an inner water vessel in the tank. The carbide hopper is attached to the top of the bell.

Acetylene Gas Machines.

Matthews, F.
Montreal
17406
Aug. 28, 1899

Carbide falls into water. The generator contains a hollow stem in the centre, its four sides being connected with hinged carbide buckets, the catch of which is released by a rod extending up through the stem, and worked by the movement of the gas bell. The carbide buckets are overturned in succession. A safety blow-off pipe is provided.

Acetylene Lamps.

A carbide receptacle, tapered downwards, is closed at top by soldered plate carrying gas eduction pipe, and at bottom by a cap, through which passes a wick to convey water to the carbide. This device may be applied to any oil lamp by using the oil reservoir as the outer water reservoir.

Dewey, C. and Chown, J. A. London 18189 Sep. 8, 1899

Acetylene Generators.

A device for generators in which carbide is intermittently fed into water, to prevent air entering generator when water is being changed. It consists of a pipe connection, combined with a water seal, between the water-space of the generator and the outer air, and also between the gas-space of the generator and the water-space of the gasholder, and thirdly, between the water-space of the generator and the gas-space of the gasholder.

Adolfsson, A. E. Stockholm 19345 Sep. 26, 1899

Acetylene Generators.

A water-jacketed cylindrical vessel to contain carbide has open ends adapted to be closed by gas-tight stoppers. A central hole in the upper stopper receives the nozzle of a flexible water reservoir. The nozzle is provided with a stopcock, which is so adjusted that when there is no pressure upon the water reservoir no water passes the cock. The gas eduction tube from the carbide chamber communicates with an ordinary gasholder, the bell of which carries upon its top an arm which extends over the flexible water reservoir when the bell is filled with gas, but which comes in contact with, and compresses, the reservoir as the bell sinks. The pressure upon the reservoir causes water to pass the stopcock and flow to the carbide.

Ginnasi, F. New York 20256 Oct. 9, 1899

Generating Acetylene Gas.

Carbide falls into water. The generator is a water tank provided at the top with a pipe for the gas and with a shoot with its lower end inclined. The carbide is placed in a bottomless box travelling on rails and divided by vertical partitions, each compartment being divided by a horizontal movable partition. As the gasholder descends it draws the carbide box by a cord over the mouth of a funnel, allowing one compartment to empty; with the rise of the bell the carbide box is drawn away, this operation continuing until the carbide is exhausted.

Llorens, J. Barcelona 20354 Oct. 10, 1899

Acetylene Lamps.

A cartridge to give a steady flame throughout the life of the carbide charge when the end of the cartridge is immersed in water. In making the cartridge a strip of absorbent material so convoluted as to serve the purpose of a confining and divid-

Lewis, T. H. London 22389 Nov. 9, 1899

ing frame for the carbide, and to provide room for expansion during decomposition, is employed. The valve for admitting water comprises a metal disc with slits for tongue pieces, a cork packing ring, and an absorbent pad.

Acetylene Lamps.

Richter, S.
Nuremburg
22788
Nov. 15, 1899

The piston is removed from a cyclist's tyre inflater. The cylinder is then charged with carbide and closed by a cap. The upper part of cap consists of two cylinders arranged one inside the other, and through which is a gas channel. An elastic ball, which acts as water reservoir, has a valve cock, and is attached to projecting side tube of inflater. Water flows from the ball to the carbide in inflater cylinder. The generated gas passes through openings and channel in cap and escapes through drying chamber to burner.

Acetylene Generator.

Turner, T. G.
New York
23179
Nov. 21, 1899

21 claims. Each carbide container is made of glass or other frangible and fireproof material, into which carbide is packed at place of manufacture and hermetically sealed. When one of these containers arrives at inlet of feed arrangement it rolls laterally off inclined periphery of feed wheel and drops upon grate just over water in generator, where it is broken. If desired, the carbide feed may be automatically controlled by pressure of gas within apparatus. The pressure, by displacement of water, may cause float to rise and press brake shoe against friction wheel and hold feed mechanism at rest. Diminution of pressure allows level of water in basin to sink, and permits float to descend and release mechanism.

Acetylene Generators.

Smith, G. G.
Florence
23309
Nov. 22, 1899

An elevated water tank is provided for each generator. Each generator contains a cylindrical closed holder charged with carbide. Between bottom plate of generator and bottom of holder is an upwardly projecting spike surrounded by a spring, which supports the bottom of carbide holder just above spike. A spiked rod also passes vertically through top of generator, and is held in position by a spring. This spike comes in contact with cover of carbide holder. Each holder contains sufficient carbide to fill the bell of the gasholder. When bell sinks to certain point one of the carbide holders is automatically punctured, and simultaneously water is allowed to flow to the generator in which the holder is situated. Each complete descent of the bell brings another carbide holder into operation.

Acetylene Generator.

A vessel is divided by a vertical partition into two chambers, one of which is partially filled with water and contains in its upper portion a carbide chamber terminating at bottom in a feeding device. The feeding device consists of a drum having longitudinal compartments for receiving carbide, and which are shaped like screw-threads to ensure gradual discharge of their contents. When the carbide drops through the discharge opening it is caught by a wheel beneath. The wheel is provided with a number of pockets having bottoms of some porous material. The wheel dips in the water to about half its height, and is rotated from the shaft of the feed drum by suitable means, so that the pockets are always wet. Thus, dust-like particles of carbide are decomposed upon the porous bottoms of the pockets, and the lumps are carried below the water by the wheel In the bottom of the second vertical chamber is a motor for the carbide-feeding device. This motor is driven by the gas generated in the first chamber. It consists of a cell wheel enveloped by a liquid of high specific gravity. The upper portion of the second chamber is a gas reservoir and contains a pressure-equaliser consisting of a vessel, having one of its walls constructed of flexible material pressed outward by a spring.

Adolfsson, A. E.
Stockholm
23937
Dec. 1, 1899

Supplying Water to Generators.

A pump is situated in the centre of a gasholder tank, and is actuated by the movements of the bell. A pipe and suction valve is provided between the water supply and the pump, and a delivery pipe, with or without a valve, extends from the pump to a point above the highest point of the generator to which the gasholder is connected. The plunger of the pump is connected by a rod with the crown of the gas bell. As the bell rises and draws the plunger with it, water is sucked into the pump; when the bell falls, the plunger is forced down, and the water is discharged into the generator.

Carey, J. W.
Brisbane
23988
Dec. 1, 1899

Acetylene Generators.

Relates to mechanism whereby carbide is automatically discharged into water by the descent cf gasholder bell to certain point, and the discharge is prevented by its ascent. Also to a safety arrangement whereby the movement of distributing drum is arrested if the principal pawl and ratchet wheel mechanism do not immediately come into gear. The drum is provided with suitable number of tubes, each of which receives sufficient carbide for the evolution of a determined quantity of gas of less

Rouma, A.
Belgium
24364
Dec. 7, 1899

volume than the capacity of gas bell. The drum is keyed upon a vertical shaft provided at lower end with bevel wheel which engages the bevel wheel of a horizontal shaft.

Acetylene Lamps.

Ströher, J.
Düsseldorf
196
Jan. 3. 1900

Several carbide and water compartments are arranged independently of each other, and can be brought into action in succession. The carbide and water receptacles are preferably arranged in circle, and separated by partitions. A water supply pipe from upper reservoir, having controllable valve, is bent sideways below the valve, and is capable of turning on vertical axis. By turning this pipe the water may be made to flow into any desired compartment, and reach carbide behind that water compartment. An index hand to show into which compartment water is being directed is provided in top of reservoir.

MISCELLANEOUS ACETYLENE PATENTS

NOTE.—Patents relating solely to constructive details of electric furnaces are not included.

Willson, T. L.
New York
16342
Aug. 27, 1894

Producing Metallic Carbides and Acetylene therefrom.

Production of carbide from lime and carbonaceous matter in the electric furnace, and the evolution of acetylene by the action of water on the carbide.

Willson, T. L.
New York
16705
Sep. 1, 1894

Producing Metallic Carbides and Acetylene therefrom.

As above.

Willson, T. L.
New York
21222
Nov. 5. 1894

Production and Utilisation of Acetylene.

The acetylene from carbide is diluted with a certain proportion of air in a holder.

Gearing, E.
Harrogate
1807
Jan. 25, 1895

Producing Carbide.

An electric furnace with a travelling electrode and feed hopper.

Bullier, L. M.
Paris
1953
Jan. 28, 1895

Carburetting Air and Gases.

Claims the admixture of acetylene with gases for imparting or increasing illuminating power.

Bullier, L. M.
Paris
2820
Feb. 8, 1895

Manufacture of Carbides of Earth Metals.

Manufacture of various carbides and acetylides of the rare earth metals as cerium, thorium and lanthanum in the electric furnace.

Rendering Acetylene suitable for Burning.

Acetylene is diluted with nitrogen, preference being given to a mixture of equal parts.

Bullier, L M.
Paris
6101
Mar. 23, 1895

Enriching Water Gas with Acetylene.

Acetylene is added to water gas practically at the place of consumption.

Dickerson, E. N.
New York
11848a
June 18, 1895

Manufacture of Illuminating Gas.

Acetylene is added to illuminating gas or enriched water gas.

Willson, T. L.
New York
13750
July 18, 1895

Production of Illuminating Gas.

Non-luminous gases are enriched by adding the gas produced by subjecting acetylene to heat.

Willson, T. L.
New York
13766
July 18, 1895

Production of Cyanogen Compounds.

A mixture of calcium and barium or sodium carbides is converted into cyanides by the joint action of nitrogen, water vapour, and heat.

Frank & Caro
Charlottenburg
15066
Aug. 10, 1895

Production of Calcium Carbide.

Carbide is made by feeding lime and carbon into the arc produced by an alternating current.

Willson, T. L.
New York
15360
Aug. 15, 1895

Production of Phosphorus.

Tricalcic phosphate mixed with carbon is heated in electric furnace to yield calcium carbide and free phosphorus.

Hilbert & Frank
Charlottenburg
18785
Oct. 7, 1895

Manufacture of Carbonic Acid Gas.

The carbon monoxide produced as a waste product in manufacture of calcium carbide is converted into carbon dioxide by passage over heated cupric oxide.

Ellworthy & Henderson
Bombay & London
19445
Oct. 16, 1895

Producing Carbides, Acetylene, etc., etc.

The numerous claims include production of calcium carbide by passing a highly heated hydrocarbon through a calcium compound; and production of acetylene by passing highly heated hydrogen, or a gaseous fluid containing hydrogen, through car-

Maxim, H.
New York
1905
Jan. 27, 1896

bon. When producing calcium carbide, ordinary limestone, instead of lime, is employed, and when making an illuminating gas in connection with the manufacture of the carbide, a sufficient excess of carbon is mixed with the limestone, not only to produce the carbide, but also to reduce the carbonic acid set free from the limestone to carbonic oxide.

Production of Acetylene with other Gases.

Lewes, V. B.
Greenwich
6922
Mar. 30, 1896

Acetylene mixed with other hydrocarbons is produced by the action of water upon calcium carbide mixed with various other carbides.

Producing Carbide.

Pictet, R. P.
Geneva
9358
May 2, 1896

The lime and carbon mixture is heated with an oxyhydrogen jet before it reaches the electric furnace.

Burning Acetylene.

Coppeaux, C.
Brussels
9630
May 6, 1896

The acetylene flame is fed with a forced current of hot or cold air, produced either by a fan or by some other air-compressing device.

Purifying Acetylene.

Bauer-waerts, E. H.
Brussels
11706
May 29, 1896

Purifying acetylene by passing it through lime, or lime mixed with iron sulphate and sawdust, then through acidulated water, through caustic soda or potash solution, and finally through a drying material such as sawdust or bran.

Burning Acetylene.

Thorp, T.
Marsh, T. G.
Manchester
12942
June 12, 1896

Acetylene is mixed with air by passing from a holder under pressure through an air injector into the delivery pipes or a second holder.

Producing Calcium Carbide.

King, R.
and
Wyatt, F.
New York
13881
June 23, 1896

Pulverised coke and lime in about equal proportions are mixed together and formed into a mound around a core of conducting material supported in vertical position between two superposed electrodes. The vertical centre of the mound is heated to incandescence by passing an electric current through the electrodes and core. A nugget of carbide is formed, and as the mixture fuses, the upper electrode descends. The carbide nugget is withdrawn while hot, a new core is then inserted, and the process is repeated. The advantages claimed are that no furnace is required, and that the process is practically continuous. An improved electric furnace is also described for use when desired.

Use of Acetylene in Motors and Ordnance, and for Producing Explosions.

Fig. 1 shows an automatic generator in which water is sprinkled over carbide; Fig. 2 an automatic generator in which carbide falls into water; Fig. 3 a generator in combination with a horizontal engine; Fig. 4 a generator or reservoir of acetylene fitted to a gun. Acetylene is made and stored in a suitable vessel under pressure. The gas may be employed by itself expansively to take the place of steam in steam engines, or it may be mixed with air or other gas or gases to form an explosive mixture, for use in the same way as ordinary gas in gas engines.

Gowlland, W. and C. S.
London
14375
June 29, 1896

Purifying Acetylene.

Acetylene is passed through finely-powdered iron, then through concentrated sulphuric acid.

Isaac, G.
Charlottenburg
15139
July 6, 1896

Producing Carbide.

Preliminary heating of the carbon and lime to form carbide, by means of a furnace or other arrangement, before the current is turned on.

Haviland, F. H.
Bournemouth
15489
July 16, 1896

Producing Carbide.

A flux is added to the mixture of lime and carbon, enabling a lower temperature to be employed. 10 per cent. of calcium fluoride is recommended.

Bullier, L. M.
Paris
16255
July 22, 1896

Purifying Acetylene.

The gas is bubbled through calcium chloride solution cooled to—20 and—40°C, then through 40 per cent. sulphuric acid at the same temperature, through a solution of lead salts, and lastly over crystallised calcium chloride.

Pictet, R.
Geneva
18208
Aug. 17, 1896

Inflating Floating Appliances.

A receiver charged with calcium carbide, or other suitable carbide, is connected to the bag or apparatus to be inflated, and is so arranged that when the apparatus is thrown into the water, water penetrates into the receiver, and the acetylene passes into the flexible apparatus and inflates it.

Matignon, L.
France
20324
Sep. 14, 1896

Production of Acetylene.

The carbide is mixed with an inert material to retard the production of acetylene on contact with water.

Deuther, J. A.
Boston, U.S.A.
20598
Sep. 17, 1896

Production of Acetylene.

Letang, M. P.
21572
Sep. 29, 1896

The carbide is covered with a protective coating or paint. The one recommended is composed of glucose, petroleum, and chalk.

Apparatus for Containing and Supplying Liquefied Gas.

Fournier, J. B.
Paris
21695
Sep. 30, 1896

Relates to use of liquid acetylene for lighting, and for inflating pneumatic tyres. Comprises a metal reservoir, a device with one or two valves for charging and discharging, and a safety device fitted with a reed, syren, or other sonorous apparatus indicating the extent to which the reservoir has been filled.

Oving, H. E.
Rotterdam
23670
Oct. 24, 1896

Mixing Acetylene with Air.

Acetylene and air are mixed in a special apparatus in definite proportions as required.

Signal Lights.

Lewes, V. B.
Greenwich, London
24365
Oct. 31, 1896

Cartridges are charged with a mixture of calcium phosphide and calcium carbide, which, on contact with water, evolves a spontaneously inflammable illuminating gas. The cartridges may be attached to buoys, torpedoes, etc.

Producing Calcium Carbide.

Maxim, H.
London
25611
Nov. 13, 1896

Numerous claims include "the superheating of previously heated fuel-gas and air by the combustion of a portion of such heated or superheated gas;" and the "process of making calcium carbide, which consists in fusing the carbide-forming material by the heat of combustion, and converting the said material into carbide by the aid of electricity."

Turr, R.
Paris
26041
Nov. 18, 1896

Incandescent Mantle with Acetylene.

A burner of the Bunsen type is supplied with acetylene under pressure, a mantle being suspended in the flame. Several forms of burner are shown.

Producing Calcium Carbide.

Kiesewalter, A.
Limburg-on-Lahn, Germany
27744
Dec. 5, 1896
Cl. May 6, 1896

Electricity is not employed. Calcium carbide is produced in retorts, or muffle furnaces, or such furnaces in which the material to be treated is hermetically enclosed against the action of the outer air and of the fire gases. A temperature of 1,300° C. to 1,500° C. must be obtainable. To the mixture of lime and carbon a flux is added. Either of the following mixtures may be used:—lime, 45 parts; carbon, 45 parts; potassium hydrate, 10 parts; tar, 20 parts; zinc, 25 parts; *or*, lime, 30 parts; magnesia, 20 parts; soda, 15 parts; carbon, 55 parts;

tar, 22 parts; Zinc, 30 parts. It is asserted that the correct formula for calcium carbide is Ca OC_2, not Ca C_2.

Storing Acetylene.

Acetylene is dissolved under pressure in certain liquid hydrocarbons, such as alcohol, ether, benzene, phenols, furfurol, etc., or mixtures of these.

Claude, G. Hess, A. Paris 29750 Dec. 24, 1896

Agglomeration of Carbides.

Pulverised carbide is placed in a rigid sheath or casing, and the interstices between the pieces of carbide are filled with bitumen mixed with 3 to 5 per cent. of tallow, or fine grain sand. When the sheath is completely filled, it is covered with waterproof paper or fabric. The shape of the cartridge, with or without longitudinal slits along it, and the agglomerating material used in its construction (tar, bitumen, sand, etc.), is varied in accordance with the required speed of decomposition.

Sales, R. de Lyons 1653 Jan. 21, 1897

Acetylene Jet for Optical Lanterns.

An arrangement to carry three burners in such position that their flames are presented to the condenser edgeways, the middle burner being fixed lower than the outer ones. The two outer burners are inclined inward towards the middle one. At suitable distance from burners is a parabolic reflector.

Thorn, F. S. and Hoddle, C. London 2260 Jan. 28, 1897

Receptacle for Storing Calcium Carbide.

A receptacle with double neck forming channel for luting. The cover has two collars, the inner one to drop into the channel containing a luting.

Thorn, F. S. and Hoddle, C. London 2261 Jan. 28, 1897

Producing Calcium Carbide.

The mixture of raw materials is first highly heated with the aid of fuel gas, and then passed into a bath of calcium carbide maintained in a molten condition by means of an electric current. A quantity of the carbide thus formed is withdrawn through one of the electrodes, which is a tube of carbon. A certain quantity of molten carbide must always be left in the furnace for continuing the process.

Maxim, H. London 2894 Feb. 3, 1897

Producing Acetylene and Carbon Dioxide.

Carbon dioxide is mixed with the acetylene at the time of generation, mixtures capable of evolving carbon dioxide being added to the carbide.

Stattler, K. Stretjz, A. Vienna 4428 Feb. 18, 1897

Producing Acetylene.

The carbide is made to absorb some fatty or oily substance impermeable to water, such as oils and varnishes, tar, and the like.

Bosca, F. Turin 4675 Feb. 20, 1897

Connecting Carbide Containers to a Water Vessel.

Vaughan-Sherrin, J. 10877 May 1, 1897

The carbide in small pieces is placed in tins with soldered ends. A circular portion is cut out of one end leaving a narrow flange all round. The flange is placed in a recess, with rubber packing provided in the end flange of a tap or valve fixed to the water vessel. The carbide tin is pressed against the rubber packing ring by any suitable means.

Producing Acetylene.

Smith, F. H. Dunblane 13103 May 27, 1897

Calcium carbide in powder or a crystalline state is compressed into tablets with or without the use of an adhesive. The tablets are coated with wax varnish or water-proof material.

Piatti, A. and Co. Rome 14505 June 15, 1897

Burning Acetylene.

10 to 50 per cent. of acetylene is mixed with the gas obtained by carbonising straw, etc.

Mixing Acetylene with Alcohol Vapour.

Bean, H. A. London 14700 June 17, 1897

Acetylene is passed through a vessel containing fibrous material soaked in alcohol, thus impregnating the gas with the vapour of alcohol.

Mixing Acetylene with Alcohol Vapour.

Bauer-waerts, E. F. Brussels 15369 June 26, 1897

Acetylene gas before being burnt is passed through a vessel containing a mixture of alcohol and sulphuric acid, to carburet and purify it.

Production of Acetylene.

Edwardes, E. J. London 16738 July 15, 1897

Porous material is traversed by the water before it attacks the carbide; thus the gas is gently and continuously disengaged.

Manufacture of Diluted Acetylene.

Lewes, V. B. Greenwich 17749 July 28, 1897

A mixture of methane, hydrogen, and carbon monoxide is made in an apparatus of the water gas type: it is passed through a scrubbing tower, and in a moist condition traverses a column of carbide, the evolved acetylene mixing with the gas. A valve is provided in the carbide container to allow carbide to drop into water to increase the amount of acetylene. 10 per cent. of acetylene with a gas consisting of 52 per cent. of hydrogen, 16 of carbon monoxide, and 32 of methane has been found to be satisfactory.

Producing Acetylene.

A device for providing means whereby surplus gas produced when generating acetylene may be led away to a place of safety, or stored in another holder.

Hacking, L. A. Blackburn 17854 July 30, 1897

Producing Carbides.

The carbide-producing mixture is fed between electrodes in the form of rotating rolls. The material passing between the rotating electrodes is converted into carbide, and falls to the bottom of the furnace. Baffle plates are placed below the electrodes to prevent the too rapid fall of the carbide; and at regular intervals a liquid, such as coal oil or kerosene, is allowed to fall by gravity through a series of small pipes upon the electrodes, in order to prevent carbide adhering to them.

Kenevel, J. W. Spofford, C. A. and Mead, J. H. New York 19512 Aug. 24, 1897

Producing Calcium Carbide.

Improvements upon Patent No. 9358 of 1896. To the mixture of lime and coke is added some reducing substance (such as coal, pitch, etc.), at high temperature, with or without the addition of fluxes. These substances are introduced into a suitable furnace, into which air is brought by tuyeres, which air, in oxidising hydrogen and carbon, heats the substances intensely before they are brought under the influence of the electric arc. A special form of furnace.

Pictet, R. P. Geneva 21508 Sep. 20, 1897 Cl. Feb. 20, 1897

Enriching Coal Gas.

Coal gas is passed into calcium carbide either alone or mixed with hygroscopic materials.

Pilous, E. Vienna 23237 Oct. 9, 1897

Producing Acetylene.

Carbide is coated with some substance insoluble in water. When wanted for use a solvent suitable for removing the coating is added to the water.

Lundstrom, C. J. Stockholm 23793 Oct. 15, 1897

Producing Carbides.

A mixture of slaked lime and powdered carbon is mixed with some liquid or adhesive substance and compressed into bricks and dried. The bricks are then broken into small pieces and introduced into an electric furnace with a movable bottom. The water gas obtained as a bye-product may be used for any industrial purposes.

Memmo, R. Rome 24077 Oct. 19, 1897

Carbide Containers.

A perforated cylinder with a removable cap at each end. The cylinder or tube is lined inside with thin soluble paper or similar material. One end is preferably tapered so that it may be telescopically fitted into the untapered end of a twin tube or cylinder.

Bond, E. S. Staffordshire 26843 Nov. 17, 1897

Producing Acetylene.

Lazarus, W. J. Duren 27639 Nov. 24, 1897

Carbide is impregnated with paraffin or other similar material, and after being powdered is made into cartridges, either by compressing it or packing in metal envelopes luted with an impermeable substance.

Purifying the Products of Combustion.

Billwiller, J. Switzerland 28003 Nov. 27, 1897

The products of combustion are led through a cylinder divided into several compartments by strainers, some of which contain a material like pumice stone soaked in a 50 per cent. solution of potassium carbonate or such liquid.

Producing Carbide.

Hurtenstein, H. L. Bellaire U.S.A. 28226 Nov. 30, 1897

Limestone is mixed with a solid fuel and calcined with the aid of a forced air supply, or the crude limestone may be calcined by a combustible gas. Into the calcined mass, while in a heated condition, a suitable proportion of pulverised coke is blown by a combustible gas under pressure. The particles of coke thus intimately mixed with the lime serve as conductors through which an electrical current is passed. The gas serving as a vehicle for the injection of the pulverised coke is also consumed, increasing the degree of heat and furnishing a constant supply of the combustible ingredients.

Enriching Coal Gas.

Wigham, J. R. Dublin 28526 Dec. 3, 1897

Acetylene is used for enriching coal gas by means of well-known devices for the exact adjustment of the ingredients of the mixture.

Producing Calcium Carbide.

Bastick, J. Manchester and Thornton, A. W. Wetherby 29008 Dec. 8, 1897

The required quantities of coke and lime, either separate or roughly mixed, are passed simultaneously to a grinding machine, then reduced to the required size and thoroughly mixed together in the grinding machine and its hopper prior to entering elevator buckets. The ground and mixed material is elevated to a conveying trough, by which it is conducted to the electric furnace.

Production of Calcium Carbide.

Bergmann, F. J. Germany 29384 Dec. 11, 1897

Carbide is produced without electricity. A water-jacketed furnace is kept in continuous working, and a mixture of coal and lime is burned in the presence of a blast of oxygen or oxygen and air. The furnace contains three chambers, the middle being charged with lime and coal, while the two outer ones are charged with fuel. Manganese oxide is the substance employed to obtain a supply of oxygen from the air.

Producing Acetylene.

Carbide broken into small pieces is heated and then soaked in a liquid made of glucose and some fatty body, a new body Ca_4C_9 being formed, which may be moulded as required. It is coated with a protective covering.

Yvonneau, E. C. Paris 30833 Dec. 30, 1897

Producing Calcium Carbide.

Powdered lime is mixed with about an equal weight of coal-tar pitch, or similar material, and heated in a retort for fifteen to thirty minutes. The hard coke-like product (preferably pulverised) is then converted into carbide in the electric furnace in the usual manner.

Leede, J. Minneapolis 32 Jan. 1, 1898

Producing Calcium Carbide.

A pencil or block is made with a mixture of pulverised chalk or lime with coke or coal breeze. This pencil is fed through an opening in the electric furnace to the arc formed between the carbon electrodes.

Kelly, W. J. and Roantree, H. London 1819 Jan. 22, 1898

Producing Carbide.

Briquettes of any suitable shape and size are made by mixing carbon and lime in proper proportions with a binder, such as sugar, asphaltum, tar, etc. The briquettes are heated in an electric furnace. It is said that these briquettes yield better results, and can be heated with less waste, than a powder.

Hewes, J. E. Philadelphia 1985a Jan 25, 1898

Producing Carbide.

Briquettes or cakes of carbide-producing materials are made and a current of electricity is passed between electrodes and through the briquettes to produce carbide. Jets of air, with or without the addition of a combustible gas, are forced into the mass.

Hewes, J. E. Philadelphia 1984 Jan. 25, 1898

Producing Carbide.

A core of calcium carbide mixed with much free fused lime is formed between the electrodes, which are gradually separating during its formation. Then the working cross-section of one of the electrodes is increased, and the core maintained in an incandescent condition by a regulated increase of current which causes it to take up carbon and form carbide concentrically around the core.

Hewes, J. E. Philadelphia 1985 Jan. 25, 1898

Mixing Acetylene with Air.

An apparatus for mixing air with acetylene, together with an arrangement for preventing fluctuations of pressure.

Thorp, T. Whitefield 2452 Jan. 31, 1898

Burning Acetylene.

Thorp, T. Whitefield 2453 Jan 30, 1898

A heat-abstracting plug of metal wires is provided at each burner and at the commencement of the service pipe to prevent back-firing.

Producing Metallic Carbides.

Diesler, C. and Dieckmann, F. Germany 4861 Feb. 2, 1898

Metallic carbonates are finely pulverised and mixed with coal-dust or carbon in the proportion of eighteen parts of carbonate to seven parts of coal-dust. The mixture is compressed into small cubes with the aid of an agglutinant such as coal-tar. The cubes are heated in retorts in which a vacuum has been produced. When the temperature has risen above 900° C. the air-pump draws off the disengaged gas. Then the pump is shut off and the retort is filled with hot monoxide or dioxide of carbon. The heat required to fuse the carbonate of lime may be produced with or without the aid of electricity. The temperature must not exceed 1,200° C.

Producing Acetylene.

Gearing, E. Harrogate 2997 Feb. 5, 1898

Carbide in powder is mixed thoroughly with tar, and the resulting mass is heated till the tar is carbonised, forming briquettes.

Purifying Acetylene.

Etaix, L. Paris 3914 Feb. 16, 1898

Commercial bleaching powder or other hypochlorite is used to remove phosphuretted hydrogen from the gas. The gas afterwards passes through caustic soda.

Producing Carbides.

Landin, J. Stockholm 4033 Feb. 17, 1898

The pulverised carbide-producing materials are mixed with tar or similar substance, and the mass is pressed into briquettes or rods. These briquettes are then heated, preferably under pressure, to 300° or 500° C. Before making the briquettes, a substance, such as calcium chloride, may be introduced to act subsequently as a flux. The briquettes or rods are finally converted into carbide by passing them between the carbon electrodes of an electric furnace.

Rendering Carbide Non-hygroscopic.

Orlowsky, von J. St. Petersburg 4298 Feb. 21, 1898

Carbide is steeped in suitable liquid hydrocarbons, such as petroleum. The carbide is preferably treated immediately after it has been crushed after leaving the furnace, and while still at a temperature of 100° to 120° C.

Receptacle for Storing Carbide.

The receptacle has a bottom provided with a projecting flange and a projecting mouthpiece capable of being closed by a screw cap. The mouthpiece serves as the filling aperture, and as the damp air attacks the carbide, acetylene rises to the upper part of the receptacle and protects the carbide from further attack. The top of the receptacle is provided with a handle.

Rümelin, L. and Aner, H. Gratz, Hungary 4459 Feb. 22. 1898

Producing Calcium Carbide.

Nine claims. Carbide is made by introducing lime and carbon into a fused bath containing manganese, calcium, and oxygen, and passing a continuous electric current through the fused mass. The flux employed consists of oxide of manganese and carbonate of calcium, which latter "reduces to nascent calcium and combines with carbon."

Hewes, J. E. 4866 Feb. 28, 1898

Producing Acetylene.

Carbide is moistened with petroleum or a mixture of mineral oils, and to the mixture is added an odorous inert oil, such as oil of roses. To decompose the carbide a saturated solution of sodium chloride is proposed.

Hviid, L. P. Copenhagen 5497 Mar. 5, 1898

Enriching Combustible Gas.

Combustible gas is enriched by acetylene, either by each being delivered from a weighted holder to another holder, or by passing through meters.

Rickman, W. London 6748 Mar. 19, 1898

Mixing Air and Acetylene.

0.4 to 1 per cent. of an oxidising gas such as air or carbon dioxide is mixed with acetylene.

Gurovitz, E. Vienna 7184 Mar. 24, 1898

Producing Amorphous Carbon from Acetylene.

Pure acetylene under a pressure of over two atmospheres is exploded in a strong closed vessel. The residual hydrogen may be used for industrial purposes. If after a preceding operation hydrogen at atmospheric pressure be left within the vessel, and acetylene under a pressure of four atmospheres be introduced, the closed vessel will contain a mixture of $\frac{1}{5}$ hydrogen and $\frac{4}{5}$ acetylene. This mixture will be decomposed with less explosive violence than when pure acetylene is used. The explosion is performed by means of an electrically heated wire.

Hubon, L. J. E. France 7139 Mar. 24, 1898

Mixing Gases in any Desired Proportions.

Acetylene Illuminating Co., Ltd. and P. C. Day London 7373 Mar. 26, 1898

Apparatus specially adapted for mixing acetylene with oil-gas or with air. The gases are fed under moderate pressure into gasholders, a separate gasholder being provided for each description of gas. Discharge pipes from the different gasholders converge at a point to form one common main. After passing through a mixing chamber the mixture may be passed into a storage holder or direct to the point of consumption.

Producing Carbides.

Aschermann, H. Cassel, Germany 7423 Mar. 28, 1898

Sulphide of iron is mixed with lime and carbon and heated in the electric furnace to obtain metallic iron and calcium carbide at a reduced electrical expenditure.

Producing Calcium Carbide.

Wilson, C. L. and others Holstein U.S.A. 7574 Mar. 29, 1898

The base and sides of the electric furnace are lined with granular calcium carbide. The mixture of lime and carbon is then fed to the arc between the electrodes, and the molten carbide collects upon the carbide-covered base and sides.

Preserving Carbides.

Roberts, T. L. New York 8010 Apr. 4, 1898 Cl. Nov. 24, 1897

States that carbide during handling in shipment may generate a spark by friction between the lumps, and this spark may explode the mixture of air and acetylene commonly present in the drums. Therefore the interstices between the lumps of carbide are filled with wheat, bran, or chaff, in order to leave little air space in the drum; and finally, before closing the drum, acetylene is passed through it to drive out any air which may still be present.

Producing Acetylene.

Tooth, E. Redfern, N.S.W. 8554 Apr. 12, 1898

Carbide is made into cartridges with lime and terebene which last may have about 2 per cent. of paraffin added to it.

Carbide Basket for Acetylene Generators.

Aykroyd, J. and B. Cullingworth 8683 Apr. 14, 1898

A basket for use in generators, in which water is admitted in or near the top of the generator. The basket is constructed of wirework, and has wirework horizontal partitions and suitable side openings for the admission of carbide. Upon the top of the basket is a sheet metal deflector, having its periphery extending beyond the side of the basket, so that water falling upon it will fall into the generator without coming in contact with the upper portion of the carbide.

Producing Acetylene.

The colophony used in a previous patent is replaced by a bituminous substance.

Piatti, A. and Co. Rome 8813 Apr. 15, 1898

Purifying Acetylene.

Bleaching powder or chloride of lime is placed in horizontal movable containers open at top. The containers are then placed in horizontal cylindrical vessels closed at one end by movable cover. The acetylene passes over or through the containers charged with purifying material in succession.

Thorn, F. S. and Hoddle, C. London 9104 Apr. 20, 1898

Producing Calcium Carbide.

A mixture of lime and carbon is placed in a crucible which is heated by a number of specially devised blow-pipe burners fed with a mixture of acetylene, marsh gas, and hydrogen. The gaseous mixture is prepared by action of petroleum vapour on heated bog iron-ore, steam being subsequently passed over the heated spongy metallic iron so produced.

Woods, J. E. T. and Byrom, W. A. London 10021 May 2, 1898

Producing Acetylene.

Carbide is dusted over with talc or lycopodium, with a view to render it more slippery and not liable to stick when being fed into the container.

Sartig, J. Cassel 10763 May 11, 1898

Washing and Purifying Acetylene.

A tank is provided to contain water or other suitable fluid. At about the centre of the tank is a dome or cylinder having a removable cover. The interior of the cylinder consists of a circular vessel, having a double bottom of wire gauze, and shaped like a bucket. The gas passing up through the washer passes through the gauze meshes. Attached to the tank is a syphon tube, which acts as a safety valve. The tank is filled with water, and after bubbling through, the gas is relieved of mechanical impurities by passage through the wire gauze. A further purifier may be employed containing solid substances, such as lime, oxide of iron, sawdust choked with acid.

Evans, E. 11676 May 23, 1898

Carbide Holder for Generators.

The carbide holder may be rotated, or otherwise moved or adjusted, to expose fresh surfaces of the carbide to the action of water. The form of holder illustrated consists of two cylinders, one of which slides telescopically within the other, the two cylinders forming a box in which the carbide is placed. Funnel-shaped openings and perforations are provided at both ends of the box, which latter may be turned upside down when necessary by means of a milled head outside the generator which is connected to the pivots in which the holder is supported.

Rigby, J. K. Thames Ditton 12022 May 26, 1898

Lighting Cycle Lamps.

MacGeorge, G. W. & Buxton, A. H. C. Paignton 13189 June 13. 1898

A device so constructed that a match or its equivalent can at any time be loaded into the lamp, and there locked in position, and also that the striking of the match and ignition of the gas or wick can at any subsequent period be effected by pressing an external button.

Condenser for Acetylene.

Forbes, C. S. Strathdon 14139 June 25, 1898

Two cylinders are joined together by a flanged horizontal diaphragm, to which they are riveted. In the upper cylindrical chamber thus formed is a tubular coil, the lower end of which is connected to a pipe, which passes through the diaphragm down nearly to the bottom of the lower chamber. The outlet gas pipe passes from near the top of the lower chamber down through its base. The gas from the generator entering the top of the coil, which is surrounded with cold water, passes down through the coil to the bottom of the lower chamber. Any water carried over by the gas is deposited in this lower chamber, where it acts as a water seal. From the upper part of the lower chamber the gas passes to an ordinary gasholder.

Calcium Carbide Manufacture.

Woods, J. E. Byrom, W. London 14453 June 30, 1898

Crude petroleum vapour is led through retorts containing oxide of iron heated, spongy iron and steam being formed with some carbon deposited. Steam is then blown through the mass, oxide of iron being formed, while hydrogen combines with the carbon to form marsh gas and acetylene. The resulting gases are led to a holder and are utilised for heating crucibles containing lime and coke for the manufacture of carbide.

Treating Calcium Carbide.

Dilberg, G. Sydney, N.S.W. 15212 July 11, 1898

Crushed carbide is stirred in a liquefied mixture of naphthalene and resin, then placed in a mould and compressed.

Protective Coatings for Carbide.

Dilberg, G. Sydney, N.S.W. 15213 July 11, 1898

Cartridges of carbide are coated with any suitable material which ultimately solidifies and forms a crust impervious to moisture and air.

Using Calcium Carbide.

Dilberg, G. Sydney 15214 July 11, 1898

The carbide is placed in a porous bag, raised, thus causing finer bubbles and more effective purification by the water of the generator.

Controlling Water Supply to Generators.

A cock plug is actuated by the movements of a gas bell by means of operating mechanism. The plug has passages so arranged that upon the sinking of the bell, caused by the exhaustion of one carbide cell, the water supply is automatically diverted to another cell. The operating wheel connected with the rotatable cock plug is actuated by a spring operating member arranged upon lower end of rack connected with gas bell.

Spanier, H.
Berlin
15732
July 18, 1898

A Carbide Holder for Generators.

The carbide holder has several compartments, each compartment being perforated at a different level, so that the water rising in the generator will decompose the carbide in one compartment before it rises to the carbide in the next.

Bailey, W. J.
and
Clapham, C.
Keighley
17127
Aug. 9, 1898

Water Jacket for Generators.

A water jacket open at top, with water surrounding sides and top of carbide containers. Any number of carbide containers can be deposited in the water jacket, from which also the water to decompose the carbide is drawn. The lowest and coldest part of the water passes to carbide, while fresh water is admitted to upper and hottest part. The mouth of each carbide container passes through bottom of water jacket, and is closed by removable gas-tight cover.

Smith, W.
Weymouth
17230
Aug. 10, 1898

Treating Calcium Carbide.

Carbide is powdered and placed in a bath of tallow or other oil, causing any free lime to saponify. The resulting thick mass is pressed whilst hot in moulds.

International
Patent Co.
Chicago
18110
Aug. 23, 1898

Combined Oil and Acetylene Lamp.

An acetylene burner is fixed in any oil or other lamp close to the oil burner. The acetylene burner may be connected by a piece of rubber tube to an acetylene generator, which may be separate or contained in the lamp. "A lamp in which oil and acetylene gas can be burnt together or separately" is the sole claim.

Morris, W. R.
and
Spraggett,
P. E.
Handsworth
19276
Sep. 10, 1898

Purifying Acetylene.

Acetylene is passed through a solution of potassium bichromate and sulphuric acid, or through a solution of chromic acid with sulphuric or acetic acid.

Landsberger, A.
Berlin
19757
Sep. 17, 1898

Treating Carbide.

Carbide is sprinkled with some essential oil, such as citronella or eucalyptus, then with purified petroleum, and finally with more of the essential oil.

Bilbie, J.
Drivet, H.
London
19786
Sep. 17, 1898

Carbide Cartridges.

Wallin, B. H. and Wendel, R. de Gothenburg
20057
Sep. 21, 1898

Porous carbide cartridges are prepared by filling unsized porous paper cases with sifted pulverized carbide, the grade of porosity being so regulated that the generation of gas has ceased within one minute after cartridge has been immersed in water.

Containers for Carbide or Acetylene Gas Apparatus.

Abeles, R. Dresden-Löbtan Germany
20646
Sep. 30, 1898

Vessels provided with "an enamel, or vitreous or like coating" are employed.

Purifying Acetylene.

Döllner, G. Berlin
22330
Oct. 24, 1898

Kieselguhr, or similar absorbent material, is mixed with a purifying solution to form a slightly moist plastic powder. The solution is an acid solution of metallic salts. The following are examples of mixtures recommended: (1) Anhydrous sodium sulphate, chloride of copper, and sufficient dilute hydrochloric or sulphuric acid to produce a warm solution, which solidifies when cool; (2) A solution of bichloride or sulphate of mercury in melted acid sodium sulphate; (3) A solution of chloride of chromium in melted chromic acid, oxalic acid, or the like. The acetylene is conducted through a mass of the material contained in a suitable receptacle.

Preparing Calcium Carbide for use in making Acetylene.

Bond, E. S. Handsworth
23346
Nov. 7, 1898

Baskets or cartridges of carbide are made by forming a spiral or coil of wire of the required diameter and length with a bottom formed of the wire itself. A paper bag or cylinder is placed either outside or inside the spiral, of a length equal to the coil spring when fully compressed. The bag is filled with carbide, the ends of the bag being held closed by the ends of the coil, but being capable of expansion when the carbide swells during generation of gas. From the sides of the coil a number of spikes project into the carbide, so that water may more readily find its way to the centre of the carbide.

Producing Carbides.

Kandler, M. and Wehner, C. Leipzig
25300
Nov. 30, 1898

Several electric furnaces are symmetrically arranged around a central and common chimney stack. The conversion of lime and carbon into carbide is not effected within the electric arc itself, but at some distance from it.

Acetylene Motor for Cycles.

Offen, C.H. Holstein
27250
Dec. 24, 1898

Water drop by drop falls upon carbide, the flow of water being regulated by a valve actuated by a handle at top of generator. The acetylene generated works an air-pump and

motor, whereupon the gas and compressed air pass through tubes into a pressure-vessel, in which they are continuously ignited with the object of transmitting the high pressure produced by the combustion through a cylinder to the crank of the cycle. The whole apparatus is suitably attached to the cycle frame.

Production of Acetylene.

Gossweiler, K. Heilbronn 27252 Dec. 24, 1898

Pulverised carbide is dissolved or suspended in a liquid such as a mineral oil, which will not decompose the carbide and which is of approximately the same specific gravity. This liquid charged with carbide is allowed to drop upon the gas-generating fluid, or the fluid may be allowed to drop upon the carbide liquid.

Producing Carbide.

Warner, R. Wade, J. and Fox, C. T. London 2497 Feb. 3, 1899

Relates to method of manufacture, in which raw materials are acted upon by incandescent gases. The raw materials are heated in a compound furnace, in one part of which preliminary heating takes place, and from which the materials are subsequently discharged into the other part of furnace for final heating and conversion into carbide. The raw materials are not allowed direct contact with injurious gases.

Carbide Container for Generators.

Watts, C. J. Guernsey 3102 Feb. 11, 1899

Porous pots resembling those employed in electrical batteries are charged with carbide, and fitted with removable caps having gas eduction pipes. Each porous pot may be impervious to water for half its height, and may be immersed in water nearly to the level of its porosity.

Buoy Lights.

Murphy, W. J. London 3747 Feb. 20, 1899

A ring of metal on top of buoy forms foundation for a circular plate dished in centre which is attached to a dome-shaped cylindrical chamber having an inner chamber for the carbide holder. Upon walls of inner chamber is a flange inclining outwards to facilitate distribution of water to carbide irrespective of angle at which buoy may float owing to swell of waves. The opening through which carbide holder is introduced is closed by a gas-tight door. A water chamber is formed above carbide chamber in the dome chamber by a horizontal partition. Water is admitted to carbide chamber through tube regulated by plug. Outside the top of dome chamber is a socket having recesses which engage projections upon the lower end of a removable mast which supports and carries gas to the burner.

Carbide Holder for Generators.

Bean, H. R. and Ringwood, H. R. London 6029 Mar. 20, 1899

The carbide vessel is made of one or more sections, each section being isolated from the others by a suitable gas-tight joint at outer edge. Each section or compartment has a channel communicating with it to convey water from the top of the holder to the carbide, and to enable the gas to be led away. The top compartment has a gas-tight cover with a raised hood upon it into which are gathered the upper ends of the channels or tubes. In the cover a number of perforations are made, varying according to the size of the vessel, through which water is conveyed to the upper ends of the tubes. The tubes are of different lengths, so that when the sections are fixed in position the upper ends of the tubes are of different levels the top compartment having its channel way lower in the hood than any of the others. The top compartment is the first to come into action, and becomes entirely surrounded with water.

Connecting Carbide Reservoirs to Gasholders.

Schubert, W. 7010 Apr. 1, 1899

A device for rapidly changing generators charged with carbide. The generators are to be connected to, or disconnected from, a displacement gasholder, from lower part of which water is supplied. The device is a gas-tight bayonet coupling joint between short pipes.

Producing Small Masses of Carbide.

Wehner, C. and Kandler, M. Leipzig 7160 Apr. 5, 1899

Small brick-like masses of carbide are produced by mixing pulverised carbide in a heated state with sugar or caramel. The mixture is moulded under pressure, and the bricks thus obtained may be coated with melted paraffin.

Manufacturing Calcium Carbide and Illuminating and Heating Gases.

Eldridge, H. Clark, D. J., & Blunn, A. A. Galveston, Texas 9156 May 1, 1899

Provides for the production of calcium carbide and "a gas suitable for general illuminating purposes" in the electric furnace "at one and the same operation." The waste heat of the furnace is employed to heat the air to be used in the manufacture of illuminating gas. The hot air is first carburetted and then mixed with acetylene. The mixed gases are finally decomposed by the heat of the furnace through which they are passed, "thereby producing a superior quality of illuminating gas."

Acetylene-lighted Projectile.

Wilson, W. J. and Turnbull, H. C. Philadel-

The projectile is cylindrical, with one end conical and weighted. The cylinder contains a carbide chamber immediately above the conical end, and above this is a gas chamber separated from carbide chamber by movable partition. Near

butt end of projectile is a chamber containing the burners, and another chamber containing lumps of metallic potassium preserved from oxidation by coal oil. The time fuse is a lead tube filled with powder. When the gun has been fired, and the projectile drops into the water, it will at first be submerged, and the potassium becoming wet will ignite, and will fire the end of the fuse. The projectile will float and assume upright position. The water will enter the conical end and attack the carbide. The acetylene will fill gas chamber and pass to burners, where it will be ignited by fuse.

phia
U.S.A.
9718
May 9, 1899

Producing Carbide.

A suitable charge of raw material is fed around vertical electrodes. A pool of molten carbide is maintained until it spreads out laterally beyond the field of reduction. The carbide and charge is then shifted, so as to bring successive portions of the charge into field of reduction.

Horry, W. S.
14261
July 11, 1899

Illuminating Projectiles.

A cylindrical shell has an upper gas chamber and a lower chamber in which carbide is supported upon a perforated shelf. The weight of carbide causes shell to float in perpendicular position when thrown into water. The gas and carbide chambers are separated by a perforated partition, and any suitable number of apertures for inlet of water are provided in walls of gas chamber. A series of burners, including an igniting device, are supported on plate on top of gas chamber. A cylindrical casing is arranged around ignition burner, and contains the terminals of electric conductors forming opposite sides of a circuit furnished with current by battery supported within a receptacle secured in upper part of gas chamber. When shell is to be used the necessary fluid is introduced into battery. The current heats resistance wire sufficiently to ignite gas. The shell is then thrown into water, and the gas formed by action of water on carbide escapes to burners, where it is ignited by resistance wire.

Rose, W. H.
Baltimore.
U.S.A.
15249
July 25, 1899

Packing Calcium Carbide for Storage or Use in Generators.

Small charges of carbide are placed in a wrapper of suitable material, such as coarse cheese cloth, and bound tightly into a compressed bundle. Preferably two or more thicknesses of the wrapper material surround the bundle. One or several of such packages may be placed in the carbide chamber of any generator. This method of packing is also recommended for the shipping and storage of carbide.

Dolan, E. J.
Philadelphia
15506
July 28, 1899

Producing Carbide.

Hartenstein, H. L. **Chicago** 16128 Aug. 8, 1899

See Patent No. 224 of 1898. Finely pulverised carbon and carbonate of lime are forced into molten blast furnace slag by a reducing gas, and then subjected to electric current.

Generating Gas having Acetylene as Base.

Richard, C. B. and Cahen, F. 17631 Aug. 31, 1899

A number of bi-metallic cartridges, containing calcium carbide, and forming a voltaic battery for decomposing the acidulated water and compressed air passed into a reservoir, are employed. The cartridges are made of a certain number of sleeves arranged one upon another. Water enters the lower part of the cartridge, and the gas produced rises into the upper sleeves and out through holes provided in the top sleeve. The electric current "decomposes the water, air, or other gas that may be used for the purpose of modifying the nature of the acetylene."

Generating Acetylene.

Kellner, C. **Austria** 21035 Oct. 20, 1899

A solution of calcium chloride is employed for decomposition of the carbide. The strength of solution depends upon the quantity of gas to be generated in given time from given quantity of carbide. A solution having spec. grav. 1·38 yields, with 600 grammes carbide, sufficient acetylene to supply table lamp for 29 hours. The carbide is always covered by the liquid, and the same solution may be used repeatedly if sufficient water be added to compensate for water decomposed by carbide.

Marine Torch.

Watson, J. A. **Washington, U.S.A.** 22227 Nov. 7, 1899

The shell may be cylindrical, with conical bottom. It has a lower carbide compartment and an upper air compartment of sufficient size to give buoyancy to the shell. Below carbide chamber is a drainage compartment to receive spent carbide. The carbide is contained in wire basket. Several small water inlets are provided in side of air chamber to permit water to flow to carbide when shell is put into water. At upper end of air chamber is top plate carrying burners, adjacent to one of which is a chamber containing calcium phosphide, which will give off spontaneously inflammable gas which will ignite acetylene. The shell is hermetically sealed until about to be used.

ACETYLENE BURNERS

Device for conducting air to the gas flame	**Schulke, A. H. J. Berlin** 10463 May 27, 1895
A small injector with ordinary union jet burner, with air holes at side of burner. The mixed gas and air pass into a mixing chamber before being burnt.	**Holliday, T. Huddersfield** 17997 Sep. 26, 1895
Nipples with fine slits or orifices combined with an outer cap enclosing the nipple. Air entering by the inlets meets the gas escaping from the nipple.	**Gearing, E. Harrogate** 21757 Nov. 15, 1895
Acetylene is forced through a tube or tubes with fine needle-hole outlets to obtain straight jets of flame (not spread out like fish-tail or bat's wing). The straight jets may be either single, or when used vertically or obliquely for lighthouse or other purposes may be arranged in groups either concentrically or otherwise. Over each jet or group of jets is suspended a tube of mica or glass. The burner tubes are surrounded with a cover of perforated zinc, copper, or other material, conical in shape, and having a bottom of the same perforated material.	**Wigham, J. R. Dublin** 4825 Feb. 28, 1896
In one form the gas enters a mixing chamber communicating with the air by oblique passages, and upon this chamber is the burner proper. The second form is for a circular flame—an argand-shaped flame with a deflector in the centre. A suitable chimney is used.	**Bauerwaerts, E. F. J. Brussels** 11707 May 29, 1896
A union jet with a small injector, the quantity of air drawn in being regulated by the size of the apertures. A needle valve is fitted in the orifice of the supply pipe.	**Holliday, T. Huddersfield** 17469 Aug. 7, 1896
The gas passes through a metallic cloth before entering the burner proper. Air inlets are arranged above the orifice where the gas enters. A mixing chamber of conical form is provided above the air inlets, and the burner is screwed on this. An apparatus for regulating the air supply is also specified.	**Gillett, S. D. Forest, G. Paris** 27086 Nov. 28, 1896

Raupp, K. H.
Mayence, Germany
27807
Dec. 5, 1896

A burner so constructed that the jets issuing from it are closer together at their bases than at their points. The burner illustrated resembles a tubular button-hook with gas orifices pierced along the outer rim of the curved end.

Billwiller, J. S.
Switzerland
29980
Dec. 29, 1896

The gas issues from a two-armed burner in two jets which meet and form a flat flame. A cone-shaped cap is fitted a slight distance above the gas exit holes, having a larger hole exactly over the gas exits. The burner is made of a bad conductor of heat, but the cap of a material that is a good conductor.

Jarre, V.
Usannez, E.
Paris
4370
Feb. 18, 1897

The burner has an annular centre, provided at the top with a recess, over which fits a plate pierced with small holes. Gas ways are arranged from the annular centre to the holes. The gas tap is cork lined.

Lebeau, J.
Belgium
9719
Apr. 15, 1897

A two-armed burner of steatite, with air passages formed in the shoulders of the burner. A small gas chamber is provided to compensate for slight variations of pressure.

Kitchen, J.
Manchester
9762
Apr. 17, 1897

The burner orifice is trumpet shaped. The nozzle of the burner is formed like a tube having its end turned inwards all round. Glass forms a cheap and efficient burner.

Turr, R.
Paris
11352
May 6, 1897

Burners constructed on the Bunsen principle. A jet of acetylene passes into a small mixing chamber having orifices for admission of air. The mixed gases pass upward into a tube capable of having its effective length adjusted by moving it up or down. The burners are shown applied to a cooking stove, a heating stove, and a soldering iron.

Ferrari, D.
Modena
12293
May 18, 1897

The flame heats a plate, which communicates heat to the gas before combustion.

Schulke, J.
Berlin
12928
May 25, 1897

This burner is composed of capillary tubes fixed in a chamber, so that the jets converge towards one another. The air is directed in parallel streams to all parts of the flame.

Gaskell, G. W. and Reeve, F. R.
14835
June 18, 1897

A series of acetylene burners in rows are arranged obliquely at a suitable angle in front of a reflector. Means are provided for adjusting the height of the burners and reflector or diffuser to any required angle.

A small metal capsule is placed on the burner to regulate the quantity of air admitted.	**Kaestner, C.** **Germany** 15060 June 23, 1897
A burner of the Bunsen type. A straight jet of acetylene passes into a small chamber having perforations in its base which admit air. From this chamber the gas jet flows upward, together with a certain quantity of air, into a tube resembling a Bunsen tube, save that its lower end is reduced; and the gas outlet may also be a reduced opening or a series of small tubes. By various combinations and modifications this burner is applied to numerous purposes.	**Ackermann, F. P. J.** **Marseilles** 19536 Aug. 24, 1897
Two converging streams of gas from a two-armed burner are each surrounded by a tube of air drawn in from air passages at the top of the burner, and form a flat flame.	**Dolan, E. J.** **Philadelphia** 20010 Aug. 31, 1897
This burner is a hollow thin-walled cylindrical body made of glass or such material. The upper rounded extremity is made paraboloidal, whilst the orifice of the gas exit is trumpet shaped.	**Lebrun, G.** **Cornaille, F.** **Paris** 20574 Sep. 7, 1897
The gas and air are separately conducted to the burner, and there impinge on one another in minute jets.	**Fraser, A. C.** **Brooklyn** 27016 Nov. 18, 1897
The burner is provided with a hood or cap having a slightly larger opening than the mouth of the burner.	**Falbe, O.** **Borchardt, E.** **Berlin** 27536 Nov. 23, 1897
A flat or convex surface is given to the top of the burner. The arc of the flame and of the burner unite at a central point of their apices.	**M'Conechy** **Glasgow** 28 Jan. 7, 1898
A disc or plate is fixed directly above the burner outlet, having a hole corresponding to that of the burner, so that the gas flame does not touch the burner.	**Schulke, E. H.** **Berlin** 926 Jan. 12, 1898
A two-armed burner with air injector holes in the steatite top. A mixing chamber is formed above the air holes.	**Legg, J.** **Cooper, A.** **Dublin** 1054 Jan. 14, 1898

Rose, A.
Handsworth
2260
Jan. 28, 1898

A cap with minute hole, and having air passages formed in it, is fixed to the burner body, air being drawn in by the stream of gas.

Worsnop, C. H.
Halifax
2366
Jan. 29, 1898

A burner fitted with a spring or pin for cleaning purposes.

Lauri, C. L.
London
9226
Apr. 21. 1898

Beneath the gas outlet orifice is a cleaning wire mounted upon a head adapted to form a gas-tight screw-joint with the cap in which the burner tip is situated. When the cap is screwed down the wire passes through the orifice, and clears it from deposit, and when the cap is unscrewed to a certain extent the wire sinks below the orifice, leaving it clear for passage of gas.

Sugg, W. T.
Westminster
9251
Apr. 21, 1898

A circular burner for use with a glass chimney. The air for supporting combustion is allowed to mingle with the gas below the point at which the gas issues from the burner.

Windham, F.
London
10815
May 11, 1898

This burner has a nozzle with a relatively small hole through which the gas escapes from the supply pipe, and a cap with a relatively large hole through which the gas passes to be burnt. It has one or more openings through which air is allowed to enter the space between the cap and the nozzle. A jet burner, a ring, double ring, and heating burner are shown.

Bray, G.
Leeds
21197
Oct. 8, 1898

A union jet burner, having on its surface a narrow ridge, on the apex of which is a small ridge in which the gas apertures are pierced.

Bray, G.
Leeds
22054
Oct. 20, 1898

Two or more jets impinge on one another. Separate orifices are used for each jet, with air inlets in the form of slits or holes.

Dolan, E.
Philadelphia
253
Jan. 5, 1899

Three forms of burner of the "duplex" type are shown. Hollow arms branching from a central screwed tube, are provided with tips arranged at an angle with one another, so that the gas jets meet and spread out into a flat flame at a slight elevation above the burner. The tips provided for the gas outlet are capped by other combustion tips.

The burner tips, of soapstone or similar material, are provided with an entrance hole and a discharge passage extending at an angle to the entrance passage and having a minute gas aperture. Lateral air inlets are provided about half below and half above the bottom of the discharge passage. Near the outer end of the passage are very small lateral passages to admit air to the column of mixed air and acetylene near the point of combustion. The tips are arranged at an angle to form a flat flame; the body of the burner projects upwards and close to the undersides of the flame from the burner tips, and the projecting mass "will be heated by the flames and will react upon the gas, promote its combustion, and heat the air rising from below."

Shaffer Rochester, U.S.A.
1634
Jan. 24, 1899

To each acetylene burner, of whatever kind, a needle-hole jet is attached as a stand-by, fed by the gas at the full pressure of the holder, the flow of gas when burning not being interrupted by any valve or tap. The ordinary burner may be turned off, leaving the small jet alight, thus obviating the inconvenience of having the acetylene burner cock either fully turned on or altogether closed.

Wigham, J. R. Dublin
4365
Feb. 28, 1899

Over the burner tip is fitted a cap having a combustion slot of greater area than the slot in the burner tip beneath. Provision for introduction of air is made at a point intermediate between the slots.

Dolan, E. J. Philadelphia
6116
Mar. 21, 1899

This burner is made of very hard material, preferably precious stone. It is bored in the centre as usual and set in a metal fitting for attachment to gas pipes. On the upper rim of the metal fitting is a metal cap provided with a hole rather larger than the hole in the burner just below it, causing a space to be left between. The cap may be provided with a number of openings so as to allow the outside air to flow into this space and be drawn through the burner orifice. The employment of precious stones produces a burner of great durability, and the hole in it may be cleaned without danger of enlarging it.

Geisseler, G. Neuveville, Switzerland
7200
Apr. 5, 1899

A head of lava, steatite, or similar material is fitted to a metal pillar. Two stems are fitted into the head, each stem tapering towards the end which fits into the head, and surmounted at the longer end by a burner tip formed by an annular cup-shaped flange, and extensions provided with a discharge

Steward, D. M. Tennesse U.S.A.
15344
July 26, 1899

opening. In the flange a hole is drilled opposite the discharge opening. The two burner tips are directly opposite each other, so that the two gas jets commingle and form a flat flame. Or, a number of radial stems may be fitted in the head, each burner tip being provided with two discharge openings, so located that the jets commingle with jets from adjacent tips, one on each side, so as to form a flat flame between each pair of stems.

Trendel, F.
Berlin
18204
Sep. 8, 1899

A narrow mixing tube is arranged over the gas injector within the principal mixing chamber of a burner of the Bunsen type. The addition of this inner tube is to ensure production of a non-luminous flame under all conditions.

Compagnie Française de l'Acétylène
Paris
23032
Nov. 18, 1899

The passage into which the acetylene is injected consists of a narrow cylindrical portion, flaring at its lower end, and continued above by a conical portion. In the lower end of the cylindrical part the air and gas pass from the injector at a high speed, which decreases in the conical part with increase of pressure. The orifices of the burner consist of tubes arranged at considerable intervals apart, surrounded by a convergent outer tube, the wider end of which is downwards, and admits external air, whilst its narrower end is within the lower part of the mantle.

APPENDIX OF USEFUL DATA.

WEIGHTS AND MEASURES.

Avoirdupois Weight.

Drachms.	oz.	lbs.	qrs.	cwts.	ton.	French grammes.
1 =	·0625 =	·0039 =	·000139 =	·000035 =	·00000174 =	1·771846
16 =	1 =	·0625 =	·00223 =	·000558 =	·000028 =	28·34954
256 =	16 =	1 =	·0357 =	·00893 =	·000447 =	453·59
7,168 =	448 =	28 =	1 =	·25 =	·0125 =	12,700
28,672 =	1,792 =	112 =	40 =	1 =	·05 =	50,802
573,440 =	35,840 =	2,240 =	80 =	20 =	1 =	1,016,048

Long Measure.

Ins.	feet.	yards.	fath.	poles.	furl.	mile.	French metres.
1 =	·083 =	·02778 =	·0139 =	·005 =	·000126 =	·0000158 =	·0254
12 =	1 =	·333 =	·1667 =	·0606 =	·00151 =	·0001894 =	·3048
36 =	3 =	1 =	·5 =	·182 =	·00454 =	·000568 =	·9144
72 =	6 =	2 =	1 =	·364 =	·0091 =	·001136 =	1·8287
198 =	16½ =	5½ =	2¾ =	1 =	·025 =	·003125 =	5·0291
7,920 =	660 =	220 =	110 =	40 =	1 =	·125 =	201·16
63,360 =	5,280 =	1,760 =	880 =	320 =	8 =	1 =	1,609·315

Measure of Capacity.

Pints.	galls.	cubic ft.	litres.
1 =	·125 =	·02 =	·5676
8 =	1 =	·1604 =	4·541
16 =	2 =	·3208 =	9·082
64 =	8 =	1·283 =	36·32816
512 =	64 =	10·264 =	290·625
2,560 =	320 =	51·319 =	1,453·126
5,120 =	640 =	102·64 =	2,906·25

1 gallon = 277¼ cubic in. = 16 cubic ft. = 10 lbs. dist. water = 4·543458 litres.
cubic ft. × 6·2355 = gallons.
1 grain = ·064799 gram. 1 lb. avoir. = ·453593 kilogram.

Useful Data.

1 lb. avoir. = 16 oz. = 7,000 grains = 453·59 grammes = $1{\cdot}2152\dot{7}$ lb. troy.
1 lb. troy = 12 „ = 5,760 „ = 373·242 „ = $0{\cdot}8\dot{2}28571\dot{4}$ lb. avoir.
1 oz. avoir. = 437·5 grains = 28·35 grammes = $0{\cdot}911458\dot{3}$ oz. troy.
1 cubic cent. = ·0610270734 cubic in. = ·282 fl. drm. = ·00176 pint = ·0352 fl. oz.
1 cubic ft. = 28315·3 c.c. = 6·2321 gallons = 28·3153 litres = 997·1364 fl. oz. = 49·8568 pints.
1 gallon = ·16046 cubic feet = 277·274 cubic in. = 4·54346 litres.
1 cubic in. = 16·386 c.c. = 4·616 fl. oz. = ·0164 litre = ·02885 pint.
1 litre = ·035316 cubic ft. = ·220096 gallon = 61·0270 cubic in. = 1·761 pint.
1 fl. oz. = 28·396 c.c. = 1·7329 cubic in.
1 pint = 567·919 c.c. = ·020057 cubic ft. = 34·659 cubic in. = ·567920 litre.
1 gramme = ;002204 lb. = ·03527 oz. = 15·432348 grains.
1 cubic metre = 35·315617 cubic feet.

To convert cubic feet per lb. into litres per kilo, multiply by 63.
To convert litres per kilo into cubic feet per lb., divide by 63.

TABLE FOR THE CONVERSION OF CUBIC METRES INTO CUBIC FEET.

Cubic Metres.	Cubic Feet.	Cubic Metres.	Cubic Feet.	Cubic Metres.	Cubic Feet.
1	35·315617	35	1236·046603	68	2401·461972
2	70·631234	36	1271·362220	69	2436·777589
3	105·946852	37	1306·677837	70	2472·093206
4	141·262469	38	1341·993455	71	2507·408824
5	176·578086	39	1377·309072	72	2542·724441
6	211·893703	40	1412·624690	73	2578·040058
7	247·209321	41	1447·940307	74	2613·355685
8	282·524938	42	1483·255924	75	2648·671293
9	317·840555	43	1518·571541	76	2683·986910
10	353·156172	44	1553·887158	77	2719·302527
11	388·471790	45	1589·202775	78	2754·618144
12	423·787407	46	1624·518393	79	2789·933761
13	459·103024	47	1659·834010	80	2825·249379
14	494·418642	48	1695·149627	81	2860·564996
15	529·734259	49	1730·465244	82	2895·880613
16	565·049876	50	1765·780862	83	2931·196230
17	600·365493	51	1801·096479	84	2966·511848
18	635·681110	52	1836·412096	85	3001·827465
19	670·996728	53	1871·727713	86	3037·143082
20	706·312345	54	1907·043331	87	3072·458699
21	741·627962	55	1942·358948	88	3107·774316
22	776·943579	56	1977·674565	89	3143·089934
23	812·259197	57	2012·990182	90	3178·405551
24	847·574814	58	2048·305799	91	3213·721168
25	882·890431	59	2083·621417	92	3249·036785
26	918·206047	60	2118·937034	93	3284·352402
27	953·521666	61	2154·252651	94	3319·668020
28	988·837283	62	2189·568269	95	3354·983637
29	1024·152900	63	2224·883886	96	3390·299254
30	1059·468517	64	2260·199503	97	3425·614872
31	1094·784134	65	2295·515120	98	3460·930489
32	1130·099751	66	2330·830737	99	3496·246106
33	1165·415369	67	2366·146355	100	3531·561723
34	1200·730986				

APPENDIX OF USEFUL DATA

TABLE OF ELEMENTS.

Elements.	Symbol.	Atomic Weight.	Elements.	Symbol.	Atomic Weight.
Aluminium . . .	Al	27·0	Molybdenum . . .	Mo	95·5
Antimony (Stibium)	Sb	120·0	Nitrogen	N	14·0
Arsenic	As	75·0	Nickel	Ni	58·6
Barium	Ba	137·0	Niobium	Nb	94·0
Beryllium	Be	9·0	Osmium	Os	190·8
Bismuth	Bi	208·2	Oxygen	O	16·0
Boron	B	11·0	Palladium	Pd	105·7
Bromine	Br	80·0	Phosphorus . . .	P	31·0
Cadmium	Cd	112·0	Platinum	Pt	194·4
Cæsium	Cs	133·0	Potassium (Kalium)	K	39·0
Calcium	Ca	40·0	Rhodium	Ro	104·0
Carbon	C	12·0	Rubidium	Rb	85·3
Cerium	Ce	140·5	Scandium	Sc	44·0
Chromium	Cr	52·0	Selenium	Se	79·0
Copper	Cu	63·2	Silver (Argentum) .	Ag	107·7
Chlorine	Cl	35·5	Silicon	Si	28·2
Cobalt	Co	58·6	Sodium (Natrium) .	Na	23·0
Didymium	Di	142·5	Strontium	Sr	87·5
Erbium	Er	165·9	Sulphur	S	32·0
Fluorine	F	19·0	Tantalum	Ta	182·0
Gallium	Ga	68·8	Tellurium	Te	127·6
Gold (Aurum) . . .	Au	196·0	Thallium	Tl	204·0
Hydrogen	H	1·0	Thorium	Th	233·4
Indium	In	113·4	Tin (Stannum) . .	Sn	118·0
Iodine	I	127·0	Titanium	Ti	48·0
Iridium	Ir	192·5	Tungsten (Wolfram)	W	184·0
Iron (Ferrum) . . .	Fe	56·0	Uranium	U	236·5
Lanthanum . . .	La	138·5	Vanadium	V	51·3
Lithium	Li	7·0	Ytterbium	Yb	172·8
Lead (Plumbum) . .	Pb	206·5	Yttrium	Y	89·8
Magnesium . . .	Mg	24·4	Zinc	Zn	65·3
Manganese	Mn	55·0	Zirconium	Zr	90·0
Mercury	Hg	200·0			

COMPARISON OF THERMOMETERS.

Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.
+260	+500·0	225	437·0	+190	+374·0	155	311·0
259	498·2	224	435·2	189	372·2	154	309·2
258	496·4	223	433·4	188	370·4	153	307·4
257	494·6	222	431·6	187	368·6	152	305·6
256	492·8	221	429·8	186	366·8	151	303·8
255	491·0	220	428·0	185	365·0	150	302·0
254	489·2	219	426·2	184	363·2	149	300·2
253	487·4	218	424·4	183	361·4	148	298·4
252	485·6	217	422·6	182	359·6	147	296·6
251	483·8	216	420·8	181	357·8	146	294·8
250	482·0	215	419·0	180	356·0	145	293·0
249	480·2	214	417·2	179	354·2	144	291·2
248	478·4	213	415·4	178	352·4	143	289·4
247	476·6	212	413·6	177	350·6	142	287·6
246	474·8	211	411·8	176	348·8	141	285·8
245	473·0	210	410·0	175	347·0	140	284·0
244	471·2	209	408·2	174	345·2	139	282·2
243	469·4	208	406·4	173	343·4	138	280·4
242	467·6	207	404·6	172	341·6	137	278·6
241	465·8	206	402·8	171	339·8	136	276·8
240	464·0	205	401·0	170	338·0	135	275·0
239	462·2	204	399·2	169	336·2	134	273·2
238	460·4	203	397·4	168	334·4	133	271·4
237	458·6	202	395·6	167	332·6	132	269·6
236	456·8	201	393·8	166	330·8	131	267·8
235	455·0	200	392·0	165	329·0	130	266·0
234	453·2	199	390·2	164	327·2	129	264·2
233	451·4	198	388·4	163	325·4	128	262·4
232	449·6	197	386·6	162	323·6	127	260·6
231	447·8	196	384·8	161	321·8	126	258·8
230	446·0	195	383·0	160	320·0	125	257·0
229	444·2	194	381·2	159	318·2	124	255·2
228	442·4	193	379·4	158	316·4	123	253·4
227	440.6	192	377·6	157	314·6	122	251·6
226	438·8	191	375·8	156	312·8	121	249·8

Centi-grade.	Fahren-heit.	Centi-grade.	Fahren-heit.	Centi-grade.	Fahren-heit.	Centi-grade.	Fahren-heit.
+120	+248·0	85	185·0	+50	+122·0	15	59·0
119	246·2	84	183·2	49	120·2	14	57·2
118	244·4	83	181·4	48	118·4	13	55·4
117	242·6	82	179·6	47	116·6	12	53·6
116	240·8	81	177·8	46	114·8	11	51·8
115	239·0	80	176·0	45	113·0	10	50·0
114	237·2	79	174·2	44	111·2	9	48·2
113	235·4	78	172·4	43	109·4	8	46·4
112	233·6	77	170·6	42	107·6	7	44·6
111	231·8	76	168·8	41	105·8	6	42·8
110	230·0	75	167·0	40	104·0	5	41·0
109	228·2	74	165·2	39	102·2	4	39·2
108	226·4	73	163·4	38	100·4	3	37·4
107	224·6	72	161·6	37	98·6	2	35·6
106	222·8	71	159·8	36	96·8	1	33·8
105	221·0	70	158·0	35	95·0	Water freezes **0**	**32·0**
104	219·2	69	156·2	34	93·2	– 1	30·2
103	217·4	68	154·4	33	91·4	2	28·4
102	215·6	67	152·6	32	89·6	3	26·6
101	213·8	66	150·8	31	87·8	4	24·8
Water boils **100**	**212·0**	65	149·0	30	86·0	5	23·0
99	210·2	64	147·2	29	84·2	6	21·2
98	208·4	63	145·4	28	82·4	7	19·4
97	206·6	62	143·6	27	80·6	8	17·6
96	204·8	61	141·8	26	78·8	9	15·8
95	203·0	60	140·0	25	77·0	10	14·0
94	201·2	59	138·2	24	75·2		
93	199·4	58	136·4	23	73·4		
92	197·6	57	134·6	22	71·6		
91	195·8	56	132·8	21	69·8		
90	194·0	55	131·0	20	68·0		
89	192·2	54	129·2	19	66·2		
88	190·4	53	127·4	18	64·4		
87	188·6	52	125·6	17	62·6		
86	186·8	51	123·8	16	60·8		

Conversion of Thermometer Degrees.

°C to °F, multiply by 9, divide by 5, then add 32.

°F to °C first subtract 32, then multiply by 5, and divide by 9.

TABLE OF THE CORRESPONDING HEIGHTS OF THE BAROMETER IN MILLIMETRES AND ENGLISH INCHES.

Milli-metres.	=	English inches.	Milli-metres.	=	English inches.	Milli-metres.	=	English inches.
720	=	28·347	739	=	29·095	758	=	29·843
721	=	28·386	740	=	29·134	759	=	29·882
722	=	28·425	741	=	29·174	760	=	29·922
723	=	28·465	742	=	29·213	761	=	29·961
724	=	28·504	743	=	29·252	762	=	30·000
725	=	28·543	744	=	29·292	763	=	30·039
726	=	28·583	745	=	29·331	764	=	30·079
727	=	28·622	746	=	29·370	765	=	30·118
728	=	28·662	747	=	29·410	766	=	30·158
729	=	28·701	748	=	29·449	767	=	30·197
730	=	28·740	749	=	29·488	768	=	30·236
731	=	28·780	750	=	29·528	769	=	30·276
732	=	28·819	751	=	29·567	770	=	30·315
733	=	28·858	752	=	29·606	771	=	30·355
734	=	28·898	753	=	29·645	772	=	30·394
735	=	28·937	754	=	29·685	773	=	30·433
736	=	28·976	755	=	29·724	774	=	30·473
737	=	29·016	756	=	29·764	775	=	30·512
738	=	29·055	757	=	29·803			

UNITS OF HEAT.

The British Thermal Unit (B.T.U.), or unit of heat, is the quantity of heat required to raise 1 lb. of pure water 1° Fahr., or, more exactly, from 39·1° to 40·1° Fahr.

The Calorie, large calorie, or French unit of heat, is the quantity of heat required to raise 1 *kilogramme* of water through 1° C.

The calorie, or small calorie (with a small *c*) is the scientific unit of heat. It is the quantity of heat required to raise one *gramme* of pure water from 0° to 1° C.

The pound centigrade unit is the quantity of heat required to raise 1 lb. of water from 0° to 1° C.

B.T.U.		Ca.		ca.		Lb. C.U.		Foot-lbs.
1	=	0·252	=	252	=	0·555	=	776
3·9682	=	1	=	1,000	=	2·2046	=	3,080
0·003968	=	0·001	=	1	=	0·002046	=	3·08
1·8	=	0·4536	=	453·6	=	1	=	1,397

APPENDIX OF USEFUL DATA

Specific Gravities and Weights of Various Materials.

SOLIDS.

Metals.

Description.	Specific Gravity.	Weight in lbs. of a cubic.	
		Foot.	Inch.
Aluminium	2·67	162	·094
Antimony	6·71	418	·242
Bismuth	9·79	610	·352
Cadmium	8·60	536	·309
Calcium	1·57	98	·056
Copper, from	8·60	537	·311
to	8·92	557	·322
„ average	8·80	549	·318
Gold	19·3	1,204	·697
Iron, cast, from	7·0	437	·253
to	7·6	474	·274
„ „ average	7·22	451	·261
Iron, wrought, from	7·55	471	·273
to	7·81	487	·282
„ „ average	7·70	480	·280
Lead, cast	11·36	708	·408
„ sheet	11·4	711	·412
Magnesium	1·74	108	·062
Manganese	8·0	499	·289
Nickel	8·9	555	·321
Platinum	21·5	1,342	·776
Potassium	·86	54	·031
Silver	10·5	655	·379
Sodium	·97	60	·035
Steel, from	7·8	487	·282
to	8·0	499	·289
„ average	7·9	493	·285
Tin	7·3	456	·264
Zinc	7·1	443	·256

Alloys.

Description.	Specific Gravity.	Weight in lbs. of a cubic	
		Foot.	Inch.
Aluminium bronze (90 to 95% copper), from . .	7·7	480	·280
to . . .	8·0	499	·289
Bell metal.	8·05	502	·29
Brass, from	8·4	524	·303
to	8·6	537	·311
Bronze, from	8·4	524	·303
to.	8·7	543	·314
Gun metal, from . . .	8·5	530	·307
to	8·6	537	·311
Babbitt metal	7·3	456	·264
White metal.	7·3	456	·263

$$\text{Electrical Horse Power (E.H.P.)} = \frac{\text{ampéres} \times \text{volts.}}{746}$$

$$\text{Kilowatt} = \frac{100}{76} \times \text{E.H.P.}$$

Relation Between Pressure Expressed in Inches of Water and Pounds Per Square Inch.

Inches of Water.	Effective Pressure in Pounds per square inch.	Effective Pressure in Ounces per square inch.	
		Exactly.	Approximately.
1	0·03617	0·578	$\frac{3}{5}$ oz.
$1\frac{1}{4}$	0·04521	0·723	$\frac{3}{4}$ „
$1\frac{1}{2}$	0·05425	0·868	$\frac{9}{10}$ „
$1\frac{3}{4}$	0·06329	1·013	1 „
2	0·07234	1·157	$1\frac{1}{6}$ „
$2\frac{1}{4}$	0·08138	1·302	$1\frac{1}{3}$ „
$2\frac{1}{2}$	0·09042	1·447	$1\frac{1}{2}$ „
$2\frac{3}{4}$	0·09946	1·591	$1\frac{3}{5}$ „
3	0·10851	1·736	$1\frac{3}{4}$ „
$3\frac{1}{2}$	0·12659	2·025	2 „
4	0·14468	2·315	$2\frac{1}{3}$ „
$4\frac{1}{2}$	0·16276	2·604	$2\frac{2}{3}$ „
5	0·18085	2·893	3 „

APPENDIX OF USEFUL DATA

PHOTOMETRIC STANDARDS.	CANDLES.
English Candle (Sperm)	1
French Carcel	9·5
German Candle (Paraffin)	1·05
Hefner Unit	0·89

DENSITIES AND WEIGHTS OF GASES AND VAPOURS.

(*Winkler and Lunge's "Technical Gas Analysis."*)

Name of Gas.	Molecular Formula.	Density (Hydrogen=1)	1 Litre of Gas in the normal state weighs
			Grammes.
Acetylene	C_2H_2	12·970	1·1621
Benzene	C_6H_6	38·910	3·4863
Butylene	C_4H_8	27·940	2·5034
Carbon disulphide	CS_2	37·965	3·4017
Carbon oxysulphide	CO_2S	29·955	2·6839
Cyanogen	$(CN)_2$	25·990	2·3287
Ethane	C_2H_6	14·970	1·2413
Hydrogen cyanide	HCN	13·495	1·2091
Phosphuretted hydrogen	H_3P	16·980	1·5214
Propylene	C_3H_6	20·955	1·8775
Silicium tetrafluoride	SiF_4	52·055	4·6641

Specific Gravities and Weights of Gases and Vapours.

(*Alkali Maker's Handbook.*)

North latitude, 52° 30′, 130 feet above sea level.

Gas.	Symbol.	Mole-cular Weight.	Specific Gravity (Air=1.)	Grains per cub. foot 29·92″ and 32° Fahr.	Lbs. per cub. foot 29·92″ and 32° Fahr.[1]
Ammonia	NH_3	17	0·58890	332·96	·04757
Atmospheric air. . . .	...	...	1·00000	565·16	·08074
Bromine	Br_2	160	5·52271	3,122·1	·4460
Chlorine	Cl_2	71	2·44921	1,384·73	·1978
Carbonic oxide	CO	28	0·96709	546·78	·07811
Carbonic anhydride . .	CO_2	44	1·51968	859·21	·12274
Ethylene	C_2H_4	28	0·96744	546·98	·07814
Hydrogen	H_2	2	0·06923	39·1439	·0055919
Hydrogen chloride . . .	HCl	36·5	1·25922	711·94	·1017
Iodine	I_2	254	8·756	4,949·90	·7071
Methane	CH_4	16	0·55297	312·64	·04466
Mercury	Hg	200	...	3,914·39	·5592
Nitrogen	N_2	28	0·97010	548·47	·07835
Nitrous oxide.	N_2O	44	1·52269	860·90	·1229
Nitric oxide	NO	30	1·03767	586·66	·08381
Nitrous anhydride . . .	N_2O_3	76	2·630	1,487·46	·2125
Nitric peroxide	NO_2	46	1·592	900·31	·1286
,, ,, ...	N_2O_4	92	3·184	1,800·63	·2572
Oxygen	O_2	32	1·10521	624·85	·08926
Sulphuretted hydrogen .	H_2S	34	1·17697	665·44	·09506
Sulphurous anhydride .	SO_2	64	2·21295	1,251·19	·1787
Sulphur	S_2	64	2·2155	1,252·59	·1789
Water	H_2O	18	0·62182	351·57	·05022

[1] For calculations with large quantities of gas, it is sufficiently accurate to assume that 10,000 cubic feet weigh as many cwts. as the molecular weight of the gas divided by 4 indicates.

For example, 10,000 cubic feet of sulphuretted hydrogen weigh $\frac{34}{4}$=8·5 cwts. (exactly, it would be 8·488 cwts.).

APPENDIX OF USEFUL DATA

Calculation of Thermometric Scales.

The Centigrade thermometer is always employed in scientific work, and differs from the Fahrenheit, in that the freezing point of water is taken as 0° on the Centigrade, and 32° on the Fahrenheit scale; and the boiling point on the former is 100, whilst in the latter 212. One scale can be readily converted into the other by the formulæ:—

$$\frac{5}{9}(\text{F.}^\circ - 32) = \text{C.}^\circ$$

$$\frac{9}{5}\text{C.}^\circ + 32 = \text{F.}^\circ$$

Calculation of Change of Volume in a Gas, with Alterations of Temperature and Pressure.

The variations in volume, due to change of temperature and pressure, have made it necessary to fix a standard temperature and pressure at which all gases shall be measured, and for all scientific purposes 0° C. and a barometric pressure equal to 760 mm. of mercury have been adopted, and called the "normal" temperature and pressure.

Now it is evident that it would be practically impossible to secure these conditions, so that the usual method adopted is to measure the gas under ordinary circumstances, and having noted the temperature and pressure, to calculate what would be the volume under *normal* conditions of temperature and pressure, and this is done by the formula:

$$\frac{v\,p}{t} = \frac{v^1\,p^1}{t^1},$$

where—

v = original volume.
p = observed pressure.
t = observed temperature in (273 + °C.)
v^1 = required volume.
p^1 = normal pressure.
t^1 = normal temp. (273 + 0°C.)

This formula is adapted for any calculation as to change in volume, etc., by using v^1, p^1, and t^1 as may be required.

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Butler & Tanner, The Selwood Printing Works, Frome, and London.